DIRAC

DIgital Reliable Amp Converter

6-kW Monopolar Digital Power Supply Unit

CAENels

Gear For Science

User's Manual

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Rev. 1.3 – October 2014

MAGNET POWER SUPPLY SYSTEMS

This product is CE certified.

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Document Revision	Date	Comment
0.1	September 17th 2012	Draft release
1.0	November 30th 2012	First release of document
1.1	December 14th 2012	Minor changes and corrections
1.2	April 9th 2013	Interlock description changed
1.3	October 30th 2014	Manual graphic changed

Safety information - Warnings

CAEN ELS will repair or replace any product within the guarantee period if the Guarantor declares that the product is defective due to workmanship or materials and has not been caused by mishandling, negligence on behalf of the User, accident or any abnormal conditions or operations.

Please read carefully the manual before operating any part of the instrument

WARNING

High voltage inside, do NOT open the boxes

CAEN ELS d.o.o. declines all responsibility for damages or injuries caused by an improper use of the Modules due to negligence on behalf of the User. It is strongly recommended to read thoroughly this User's Manual before any kind of operation.

CAEN ELS d.o.o. reserves the right to change partially or entirely the contents of this Manual at any time and without giving prior notice.

Disposal of the Product

The product must never be dumped in the Municipal Waste. Please check your local regulations for disposal of electronics products.

Read over the instruction manual carefully before using the instrument.
The following precautions should be strictly observed before using DiRAC units:

WARNING	• Do not use this product in any manner not specified by the manufacturer. The protective features of this product may be impaired if it is used in a manner not specified in this manual. • Do not use the unit if it is damaged. Before you use the device, inspect the instrument for possible cracks or breaks before each use. • Do not operate the unit around explosives gas, vapor or dust. • Always use the unit with the cables provided. • Turn off the unit before establishing any connection. • Do not operate the unit with the cover removed or loosened. • Do not install substitute parts or perform any unauthorized modification to the product. • Return the product to the manufacturer for service and repair to ensure that safety features are maintained
CAUTION	• This power supply is designed for indoor use and in area with low condensation.

The following table shows the general environmental requirements for a correct operation of the instrument:

Environmental Conditions	Requirements
Operating Temperature	5°C to 40°C
Operating Humidity	30% to 85% RH (non-condensing)
Storage Temperature	-10°C to 60°C
Storage Humidity	5% to 90% RH (non-condensing)

1. Introduction

This chapter describes the general characteristics and main features of the DiRAC monopolar power supply unit series.

1.1 DiRAC Overview

The DiRAC power unit series is based on the recent AC-DC three-level ZVS converter topology and it is composed of a PFC stage combined with a buck converter into a single stage. These units are rated at a 6-kW output power and are available with different ratings for current and voltage:

- 120A@50V – **PS120050**;
- 135A@40V – **PS135040**.

The DiRAC units also are available in two different versions for the three-phase input voltage:

- 208 V(AC) – **"A"** version;
- 400 V(AC) – **"E"** version.

The resonant nature of this power supply guarantees very high efficiency, a crucial factor to take into account when maintaining into operation a large number of power supplies in the same facility.

The current control loop of the DiRAC, as for all other CAENels power supplies, is completely digital in order to guarantee the same configurability and ease of tuning to any load condition (resistive and inductive parts). A new feature of this unit is the current control algorithm, which is performed directly by the on board FPGA: the parallel nature of the computation allows to greatly reducing time delays in the feedback loop.

Output current setting is performed by the use of a DCCT (DC Current Transformer) that presents high long-term stability, good bandwidth, low noise and extremely low TC (Temperature Coefficient). The use of state-of-the-art SAR ADCs for current and voltage sensing guarantees a reduced group delay and thus higher bandwidth.

Internal interlocks and protections are redundant and distributed inside the power supply unit – e.g. the temperature is monitored by six different sensors placed in different sections of the board and the internal heatsinks.

The control board of the unit, hosting the FPGA, the diagnostic ADCs, communication sections, local control + display managing and other ancillary parts is the same used for the SY3634 and SY3662 system modules.

Remote communication is guaranteed by means of a standard RJ-45 Ethernet 10/100 auto-sensing socket accessible from the unit front panel; the power supply can also be locally monitored and controlled via an encoder and a graphic color display featuring user-friendly menus.

Mechanical dimensions of the unit are 3U × 19" × 58cm (62cm with the output connections).

1.2 Description

An example of the DiRAC system unit is shown in **Figure 1** and it is composed by a single 3U-19" crate:

Figure 1: front view of a DiRAC power supply unit

Circuit breakers, RJ-45 Ethernet connection socket, encoder for local control, fan air inlets and LED indicators are all present on the front panel of the DiRAC unit.

Two "trimmers", accessible with a little screwdriver, for regulating hardware thresholds of maximum output current and voltage are also present together with two LEMO connectors that allow monitoring of either:

a. the scaled actual maximum current and voltage thresholds that have been set via the trimmers for the DiRAC unit;

b. the scaled actual output current and output voltage monitors.

The selection between **a.** and **b.** is performed by a switch: this is also present on the front panel.

Please refer to **Section** 3 for further information about functionalities of the DiRAC front and rear panel controls and connectors.

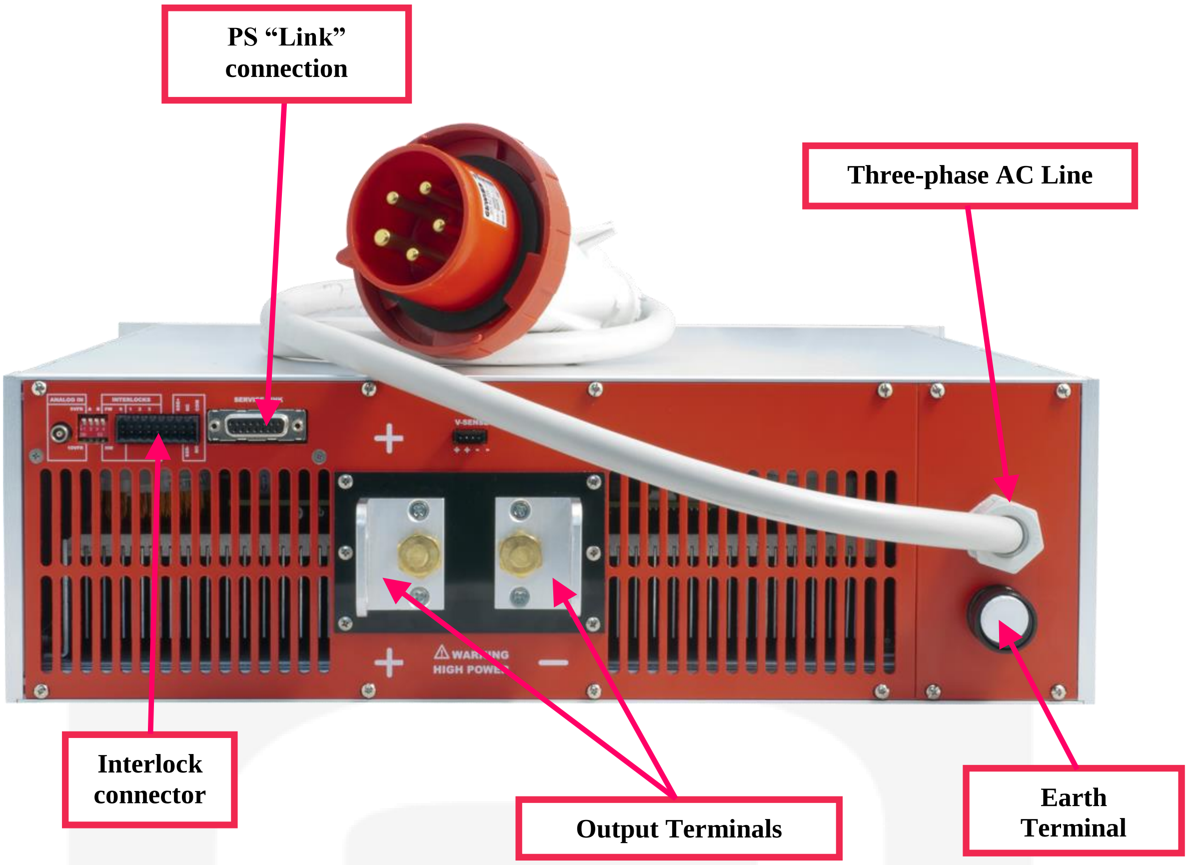


Figure 2: rear view of a DiRAC power supply unit

Channel interlock connection, "PS link" connector, additional earth terminal, output terminals, air outlets and three-phase inputs are all present on the rear panel of the system crate, as shown in
Figure 2.

A 4-switch DIP switch for general configurability and future developments is also present together with a LEMO coaxial input connector that allows controlling the unit with an external reference voltage source (one of the DIP switch is used to select the full-scale range of the analog input for the power supply to 5V or to 10V).

Voltage sensing terminals for future implementations of analog voltage-mode regulation of the power supply are also present on the rear side of the unit.

2. Safety and Installation

Please read carefully this general safety and installation information before using the product.

2.1 General Safety Information

This section contains the fundamental safety rules for the installation and operation of the system. Read thoroughly this section before starting any procedure of installation or operation of the product.

Safety Terms and Symbols on the Product

These terms may appear on the product:

- DANGER indicates an injury hazard immediately accessible as you read the marking;
- WARNING indicates an injury hazard not immediately accessible as you read the marking;
- CAUTION indicates a hazard to property including the product.

2.2 Initial Inspection

Prior to shipment this system was inspected and found free of mechanical or electrical defects. Upon unpacking of the system, inspect for any damage, which may have occurred in transit. The inspection should confirm that there is no exterior damage to the system such as broken knobs or connectors and that the front panels are not scratched or cracked.

Keep all packing material until the inspection has been completed. If damage is detected, file a claim with carrier immediately and notify CAEN ELS d.o.o. service personnel.

2.3 Injury Precautions

This section contains the fundamental safety rules for the installation and operation of the system in order to avoid injuries.

2.3.1 Caution

The following safety precautions must be observed during all phases of operation, service and repair of this equipment. Failure to comply with the safety precautions or warnings in this document violates safety standards of design, manufacture and intended use of this equipment and may impair the built-in protections within.

CAEN ELS d.o.o. shall not be liable for user's failure to comply with these requirements.

To avoid electrical shock or fire hazard, do not apply a voltage to a load that is outside the range specified for that load.

Do Not Operate Without Covers.

To avoid electric shock or fire hazard, do not operate this product with covers or panels removed.

Do Not Operate in Wet/Damp Conditions.

To avoid electrical shock, do not operate this product in wet or damp conditions.

Do Not Operate in an Explosive Atmosphere.

To avoid injury or fire hazard, do not operate this product in an explosive atmosphere.

Do Not Operate With Suspected Failures.

If you suspect there is damage to this product, have it inspected by qualified service personnel.

2.4 Grounding

To minimize shock hazard, the DiRAC power supply system must be connected to an electrical ground.

2.5 Input Ratings

Do not use AC supply which exceeds the input voltage and frequency rating of this instrument. For input voltage and frequency rating of the module see Chapter 6.

For safety reasons, the mains supply voltage fluctuations should not exceed above voltage range. The DiRAC power supply units are available in two different input rating versions:

- "A" version: 3 × 208V (AC), 47-63 Hz;
- "E" version: 3 × 400V (AC), 47-63 Hz.

Please read carefully the version "type" before connecting the unit to power mains.

2.6 Output Connectors

Do not plug or unplug output connectors when power converters are on and the power units are regulating current on the electrical load.

2.7 Live Circuits

Operating personnel must not remove the 19" crates covers. No internal adjustment or component replacement is allowed to non-CAEN ELS d.o.o. personnel. Never replace components with power cables connected.

In order to avoid injuries, always disconnect power plugs, discharge circuits and remove external voltage source before touching components (wait 5 minutes at least).

2.8 Part Replacement and Modifications

Always disconnect power plugs, discharge circuits and remove external voltage source prior to fuse replacement (wait 5 minutes at least).

Other parts substitutions and modifications are allowed by authorized CAEN ELS d.o.o. service personnel only.

2.9 Installation Instructions

Follow these instructions in order to correctly install the DiRAC power supply unit.

Please execute all these operations with the AC power main plugs disconnected.

Connect the interlock mating connector in its relevant socket (wire towards your loads). The interlock connector can be connected to the desired interlock sources directly involved in that particular unit operation. For further interlock information and pinout, please refer to section **3.2.2**.

The DC output terminals (see **Annex A - Output Connectors** for further information on how to connect them) are to be directly connected to the load – e.g. magnet. A M8 or M10 screw can be used in order to connect the load terminals to the DiRAC output connections. It is necessary to remove the plastic protection transparent cover in order to connect the load terminals to the DiRAC power supply unit.

Now you can connect the three-phase AC power connector to the mains network in order to power up the unit. Please note that the AC input requires the three-phases and the earth connections (neutral is not necessary).

3. DiRAC Description

A description of the DiRAC is herein presented with some in-depth explanations on the basic power supply functionalities.

3.1 DiRAC Front Panel

The DiRAC unit front panel is herein described as shown in **Figure 3**:.

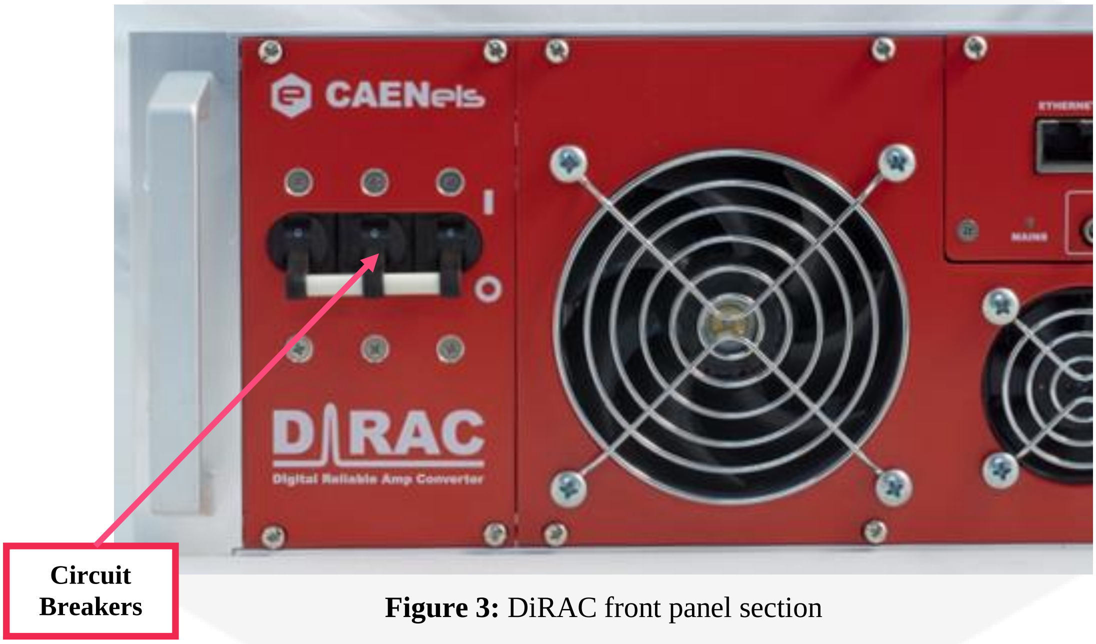


Figure 3: DiRAC front panel section

The circuit breaker, placed on the front panel, enables the supply of the power part of the converter from the three-phase input. This circuit breaker also act as protection for the DiRAC unit.

When setting the circuit breaker to position "1" – i.e. ON – the yellow MAINS LED is lit up, indicating that the power section of the converter is supplied from the AC mains.

An explanation of the front panel LEDs and functions is herein presented referring to the following Figure:

The DiRAC module front panel presents, as the SY3634 and SY3662 systems, the Ethernet RJ-45 communication socket, the colour display and the encoder (with pushbutton) that allows controlling and navigating through the module menus.

The RST – i.e. reset – pushbutton is accessible through a small hole placed in the same DiRAC front panel and can be used by a small tip.

The LEDs that can be found on the control board front panel of the unit are hereafter described:

- **ON** LED: the blue light indicates that the DiRAC power unit is in ON state and its output driver is enabled;
- **RX** LED: the blue light toggles at every "termination character" reception – i.e. *carriage return* '\r' – and it can also be interpreted as a communication heartbeat indicator;
- **LINKED** LED: the green light indicates that the DiRAC module is connected to another DiRAC module via the SERVICE LINK connection on the rear side of the crate. DiRAC modules of same ratings can work in parallel if correctly configured;
- **FAULT** LED: the red light indicates that the DiRAC power supply has experienced a generic fault that can be either an internal protection trip or an external interlock intervention. This light does not turn off after a fault until a local or a remote module reset has been performed;
- **DIAG** LED: the white light it is modulated by an internal PWM counter that is internally serviced and reset by the control electronics at every diagnostic routine execution. If this LED is not modulating its light, the internal diagnostics it is not correctly executed by the module;
- **AUX PS** LED: the green light indicates that the auxiliary power supply section voltages are present. This LED should always be turned on if the module is

working correctly since the auxiliary power section, that supplies the control electronics, is directly connected to the AC mains inputs.

It is important to notice that the blue ON light and the red FAULT light cannot be turned on at the same moment because the module cannot correctly regulate output current if a fault is experienced and the output stage of the power supply is disabled.

The **MAINS** yellow LED also present on the module front panel indicates that the power section of the DiRAC is correctly supplied: this does NOT indicate that the output is enabled (this last information is given by the **ON** indicator).

The **MAINS** LED is turned off in any of the following cases:

- the circuit breaker on the front panel is in "0" – i.e. OFF - position;
- one of the AC input phases is missing;
- the voltage level on the input AC is too low – i.e. not within indicated ratings.

Four (4) cooling fan holes are also present on the module front panel in order to guarantee correct front-to-rear air flow.

3.1.1 Maximum Output Current and Voltage Thresholds

One particular feature of the DiRAC modules is represented by the possibility of setting maximum hardware thresholds for output current and output voltage.
These values can be set via two trimmers, accessible via a small screwdriver and can be monitored by two signals fed to two coaxial LEMO connectors.

Thresholds can be set via the **MAX I** and **V** trimmers, as shown in the following figure:

In order to increase the maximum output current threshold of the DiRAC module it is necessary to rotate the **MAX I** trimmer in the clockwise (**CW**) direction and in the opposite direction if decreasing the maximum output current is desired.

The same procedure has to be followed on the **MAX V** control trimmer in order to obtain the similar behavior for the output voltage of the DiRAC module – e.g. rotate in CW direction to increase the threshold and in CCW direction in order to decrease it.

In order to monitor the set maximum thresholds for the output current and voltage of the module, the **SELECT** switch should be set to **MAX** position, as shown in the previous figure. By doing this, a scaled value of the actual set thresholds is fed through the **MON I** and **V** coaxial connectors.

The values that can be monitored on the coaxial LEMO connectors has to be interpreted as follows:

$$\begin{cases} max(I_{OUT}) = 10 \cdot MON\_I \\ max(V_{OUT}) = 10 \cdot MON\_V \end{cases}$$

where *max*(I_{OUT}) and *max*(V_{OUT}) are the maximum thresholds set for the DiRAC module and *MON_I* and *MON_V* the scaled monitor versions that can be found on the coaxial connectors for the current and voltage respectively.

The scalefactors between the real set thresholds and the scaled monitor versions are then respectively:

- 0.1 V/A for the output current threshold;
- 0.1 V/V for the output voltage threshold.

***Example*.** If the *MAX_I* signal on the on the respective coaxial connector is of 6.8V and the MAX_V signal of 2.6V, then the corresponding hardware maximum output current threshold set for that DiRAC module is of 68A and of 26V for the output voltage.

Please note that the accuracy of these monitoring signals is 1% since they are directly hardware-connected and thus not calibrated.

3.1.2 Output Current and Voltage Monitors

The actual output current and output voltage values can be monitored from the same two coaxial connectors present on the DiRAC front panel.

In order to enable the monitoring signals, it is necessary to put the **SELECT** switch to **OUT** position. By doing this, a scaled value of the actual output current and voltage are fed on the **MON I** and **V** coaxial connectors.

The values that can be monitored on the coaxial LEMO connectors has to be interpreted as follows:

$$\begin{cases} I_{OUT} = 10 \cdot MON\_I \\ V_{OUT} = 10 \cdot MON\_V \end{cases}$$

where I_{OUT} and V_{OUT} are actual output current and output voltage respectively. *MON_I* and *MON_V* the scaled monitor versions that can be found on the coaxial connectors.

The scalefactors between the real output values and the scaled monitor signals are the same as previously indicated (for the case of the thresholds):

- 0.1 V/A for the output current monitor;
- 0.1 V/V for the output voltage monitor.

Example. If the *MAX_I* signal on the on the respective coaxial connector is of 11.0V and the MAX_V signal of 1.5V, then the corresponding output current for that DiRAC module is of 110A and of 15V for the output voltage.

Please note that the accuracy of these monitoring signals is around 1% since they are directly hardware-connected and thus not calibrated.

3.2 DiRAC Rear Panel

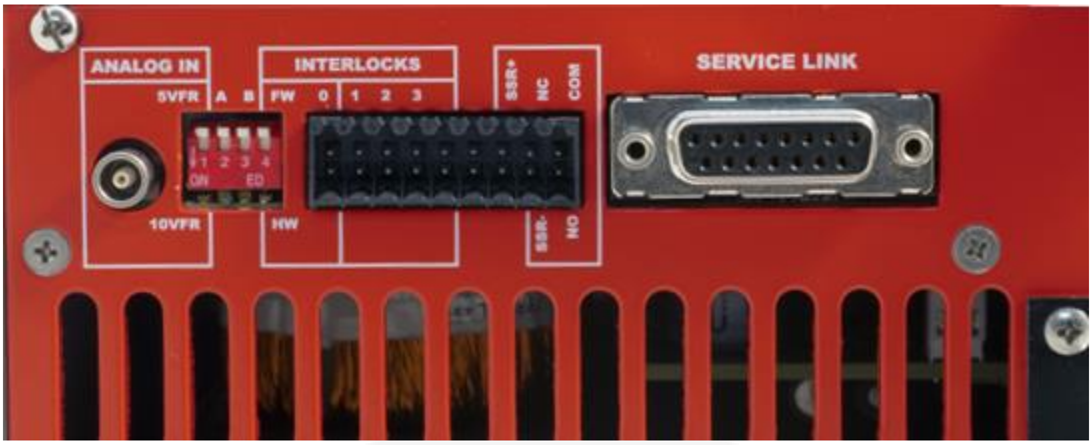
The DiRAC rear panel is presented in **Figure 4**.

Figure 4: DiRAC rear panel view

The power supply unit has on its back the three-phase input cable (no neutral is required) and an earth connection terminal behind that. Please note that the earth terminal is available only if an extra connection to earth is required but earth conductor is already connected to the chassis from the three phase input connection. Cooling aperture for air outlet are also present throughout the whole panel.

Module output connection terminals are placed in the center of the rear panel and in order to fix these connections to the load – e.g. magnet – a M8 or M10 screw can be used.

A detailed section of the DiRAC rear functionalities is hereafter shown:



The **ANALOG IN** coaxial connector is used in order to control the power supply from an external voltage source.

The DiRAC modules are digitally controlled power supply units so that the entire handling it is performed via the remote Ethernet connection. The control loop is digital i.e. - the set-point reference is given by the internal Analog to Digital Converter (ADC) and not by a Digital to Analog Converter (DAC) as it is for analog-controlled power units.

The DiRAC anyhow contains also an analog control network for both output current and output voltage.

Obviously, in order to use the power supply with an external analog reference, the digital control of the unit should be disabled. The full-scale of the external reference signal can be set by the first dip-switch position (also into the **ANALOG IN** input):

- **5VFS** to have a 0-5V full-scale dynamic range;
- **10VFS** to have a 0-10V full-scale dynamic range.

When working in analog current-controlled mode, feeding a 0V external signal will give a 0A output current on the output and feeding a 5V signal, if the dip-switch is set to **5VFS** position, will give the rated maximum current (120A for example for the DiRAC PS120050 unit and 135A for the PS135040 one).

The four input interlocks (from 0 to 3) are present on the *Weidmueller* 18-pin connectors (please see the interlock section for further details).

All interlocks, as in SY3634 and SY3662 CAENels power supply series are dry-contact type. Interlock 0 can also be configured to act in a firmware-mode (FW) or in hardware-mode (HW).

This functionality can be selected by moving the corresponding dip-switch contact to the **FW** or the **HW** position. Please note that this only refers to **Interlock 0**.

Solid-state relay contacts and magnetic-type dual contacts are found on the same interlock connector.

3.2.1 Internal Protections

Each DiRAC power supply unit is equipped with multiple internal protections (hardware and software) to avoid unwanted behaviors or eventual damages to the unit and also to let users run the power supply safely.
All hardware protections are installed into the DiRAC crate and some of them are here listed:

- CB (CrowBar protection);
- phase-fail;
- circuit breaker.

Several software protections, some of them redundant, are also implemented and here listed:

- CB (Crowbar protection);
- heatsink over-temperature;
- transformer over-temperature;
- earth leakage detector;
- fan fail detection.

Protection redundancy – i.e. hardware and software – was especially implemented in order to guarantee a double level of reliability for the specified type of power supplies.
An overview of all available protections, as well as a brief description of their behavior, is presented in the following sections.

3.2.1.2 CB – CrowBar

The A3660BS module protection against output over-voltage conditions is guaranteed by a crowbar protection circuit that, as in the case of the over-current protection one, has a double level of reliability – i.e. both hardware and software.
This protection is hardware-activated when the output voltage crosses the threshold of:

$$V_{CB\_threshold} = V_{max} + \Delta V = 60V$$

that is usually caused by a large $\frac{di(t)}{dt}$ value on a large reactive load.

The crowbar circuit also guarantees dissipation of the residual energy stored in the load when turning off the power supply output stage from a high current value on a high inductive load (i.e. 120A on a 20mH magnet).

This protection also activates a galvanically-isolated logic signal that generates a software interrupt on the on-module FPGA: when this signal is activated, the FPGA sets a flag in the status register that needs to be reset before re-enabling the channel output again.

3.2.1.3 Phase-Fail

A phase-fail circuit detects whether a phase is missing or if the voltage at the input is at a voltage level outside rated values. The power part gets powered down if one phase has a value of about 80% of rated value:

$$V_{Phase-Fail} = \begin{cases} 90V & for\ \text{“}A\text{”} - version \\ 180V & for\ \text{"}E\text{"} - version \end{cases}$$

that is about 110V × 0.8 and 220V × 0.8 respectively for the “A”-version and the “E”-version.

3.2.1.4 Circuit Breaker

The circuit breaker on the three-phases present on the DiRAC front panel protects the power supply power parts in case of malfunctioning. Please note that the circuit breaker does not switch off the control electronics auxiliary power supply so that the communication and diagnostic section of the unit is not affected.

3.2.1.5 Heatsink Over-Temperature

The temperature on the main heatsink of the DiRAC power unit is monitored in many different spots. An analog stage selects continuously only the maximum temperature among those and feeds the corresponding signal to a 16-bit ADC.

The internal logic continuously compares this temperature value with a pre-defined threshold and generates a fault condition if the measured temperature is greater than the threshold one.

Note: this value can be configured writing EEPROM “value” cell 20 (see ‘MWF Command’ Section for more information).

3.2.1.6 Transformer Over-Temperature

The logic of this temperature control is similar to the one of the heatsinks with different current sensors placed on the power transformers of the unit is monitored in An analog stage selects continuously only the maximum temperature between those and feeds the corresponding it to a 16-bit ADC.

The internal logic continuously compares this temperature value with a pre-defined threshold and generates a fault condition if the measured temperature is greater than the threshold one.

Note: this value can be configured writing EEPROM "value" cell 21 (see 'MWF Command' Section for more information).

3.2.1.7 Earth Leakage Current Detector

The earth-leakage current is detected by sensing the current flowing into a shunt resistor connected to earth. A common mode current may be present when the load or cabling to the load has a weak isolation to ground.

The voltage (proportional to the current) is measured by a 16-bit ADC so that the threshold that trips the earth current limit fault can be configured by software: EEPROM cell #31 stores this value.

Note: this value can be configured writing EEPROM "value" cell 31 (see 'MWF Command' Section for more information).

3.2.2 External Interlocks and Relay Contacts

Each DiRAC power module has different configurable input interlocks and some output status signals that are directly available on one the rear panel interlock connector.

The DiRAC interlock connector pin index is summarized in **Table 1**:

Pin Number	Function
1	Interlock 1
2	Interlock 1 return
3	Interlock 2
4	Interlock 2 return
5	Interlock 3
6	Interlock 3 return
7	Interlock 4
8	Interlock 4 return
9	*nc*
10	*nc*
11	*nc*
12	*nc*
13	Solid state Relay contact
14	*nc*
15	Magnetic Relay NC-TAP

16	Solid state Relay return
17	Magnetic Relay C-TAP
18	Magnetic Relay NO-TAP

Table 1: Rear Interlock Connector Pinout

The interlock connector is the same *Weidmuller* 18-pin male connector used in the SY3634 and SY3662 system crates and the pin-index compatibility is maintained. The corresponding pinout is shown in **Figure 5**.

Figure 5: Interlock connector on DiRAC rear panel

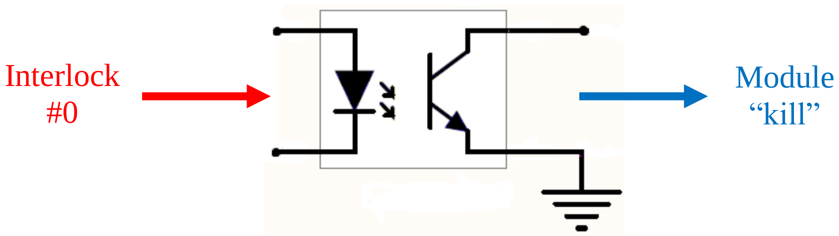
Please notice that all interlock pins are galvanically isolated from ground and outputs terminals, nevertheless the absolute maximum voltage, referred to ground, that pins can sustain is 48V.

Note: an external 24V voltage source is recommended to operate interlocks correctly.

Note: The absolute maximum current that can be sunk by the output status relays (solid state relay pins 13-16 and magnetic relay pins 15-17-18) is 100mA.

Interlock 1 (the displayed interlock name shown on the front display can be changed with the user requirements, see 'MWF command' and Memory mapping sections for further details) is can be activated when pin 1 and return pin 2 are shorted or when the contacts are open (depends on user configuration). The same behavior can be obtained for all other interlocks.

Interlock 1 has also a particular feature: it can be directly hardware-activated directly in order to shut the module power part off. This can be done by setting the corresponding dip-switch to **HW** position. The interlock circuit, when using this interlock in the hardware-mode, is a simple opto-coupler input as shown in the following diagram:



The killing action of this interlock takes place when the input photodiode is supplied and the relative photo-transistor is illuminated so that this signal can be interpreted as a true ***"kill"*** signal.

The magnetic relay provides the Output status of the module: when ON, the Normally Closed contact (**NC**, *pin 15*) switch opens and the Normally Open contact (**NO**, *pin 18*) switch closes (referring to the **COM** contact – i.e. *pin 17*).

Solid State Relay contacts are also accessible between the **SSR+** (*pin 13*) and **SSR-** (*pin 16*) signals.

The configurability of the DiRAC modules allows users to decide what interlocks to enable and what not, the interlock "tripping" level – i.e. LOW or HIGH – and the time of intervention (the time that an interlock signal has to be to the tripping level before generating a fault condition).

This information can be set and read from the module EEPROM.

An example of mating connectors for the interlocks are *Weidmuller B2L 3.50/18/180QV9 SN BK BX model*.

3.2.2.1 Interlocks Enabling/Disabling

Each external interlock on the DiRAC module can be enabled and disabled by writing to the interlock enable mask to the EEPROM cell 48. A value of '1' means that the interlock is enabled while a '0' value that the corresponding interlock is disabled.

The value to be written is the <u>ASCII string, formed by one hexadecimal digit, that corresponds to the binary enabling/disabling mask</u>; the four external interlocks are numbered from 1 to 4.

Example: if only interlocks 2 and 4 need to be enabled, the following command needs to be sent to the power supply (after having un-locked the password protection):

MWG:48:A*\r*

The sent string has to be so interpreted:

A			
1	**0**	**1**	**0**
Interlock 4 *Enabled*	Interlock 3 *Disabled*	Interlock 2 *Enabled*	Interlock 1 *Disabled*

In order to make this command taking effect it is necessary to perform a 'MUP\r' (Module Update Parameters) command – see "MUP command" section for further details.

The MRG:48\r command returns a string containing the ASCII correspondent of the interlock enable mask and contains information about what interlocks are enabled and what are disabled.

3.2.2.2 Interlocks Activation States

Each DiRAC external interlock can be chosen to trip at a HIGH or a LOW logic level. A value of '1' means that the interlock trips when the input signal to the corresponding interlock is shorted and a '0' that the corresponding interlock trips when the input is open.

The value to be written is the ASCII string, formed by one hexadecimal digit, that corresponds to the binary activation state mask; the four external interlocks, as for the interlock enable/disable mask (from 0 to 3), are numbered from 1 to 4.

Example: consider that only interlocks 2 and 4 are enabled – i.e. a "A" string is contained in the EEPROM cell 48 – and interlock 2 needs to trip when the corresponding input signals are shorted (LOW level) while interlock 4 when its input is open (HIGH level); the value to be written to the EEPROM cell 49 is the following:

MWG:49:8*\r*

The sent string has to be so interpreted:

8			
1	**0**	**0**	**0**
Interlock 4 *HIGH*	Interlock 3 *LOW*	Interlock 2 *LOW*	Interlock 1 *LOW*

In order to make this command taking effect it is necessary to perform a 'MUP\r' (Module Update Parameters) command – see "MUP command" section for further details.

Content of the interlock enable/disable mask – i.e. EEPROM cell 48 – overrides the content of the cell 49 so that the values contained in cell 49 are discarded if the corresponding bit in cell 48 is '0' (and the interlock is disabled).

The MRG:49\r command returns a string containing the ASCII correspondent of the interlock enable mask and contains information about what interlocks are activated at a LOW state and what are activated at a HIGH state.

3.2.2.3 Interlocks Intervention Time

The time of intervention for each enabled interlock on any DiRAC power supply unit can be chosen independently with a 1-ms resolution.

EEPROM cells from 50 to 53 contain information on how long an interlock input signal needs to be at its "activation" level before tripping and thus generating a fault condition. Interlock 1 intervention time is stored into EEPROM cell 50 while interlock 4 into EEPROM cell 53.

Example: consider that interlock 4 needs to trip only after 100ms it has reached its activation level. The value to be written into EEPROM memory is the following:

MWG:53:100*\r*

In order to make this command taking effect it is necessary to perform a 'MUP\r' (Module Update Parameters) command – see "MUP command" section for further details.

Note: values for intervention time have to be included between 0 and 10000 (i.e. 10 seconds).

3.2.2.4 Interlock Configuration Example

Magnets can be water-cooled and there is a usual need for an interlock in case of the water cooling system fault.

Let us consider a water flow switch that, by choice, can be connected to interlock 2 of the DiRAC interlock connector on the rear panel.

Water flow switch signals needs to be connected between pins 5 and 6 of the interlock connector (see **Figure 5**).

In order to activate only interlock 2, the following command needs to be sent to the power supply:

MWG:48:2*\r*

A correct operation of the magnet cooling keeps the interlock input pins shorted while a fault has to be generated when the input becomes open; the interlock 2 activation level needs to be set to HIGH with the following command:

MWG:49:2*\r*

The possible presence of air bubbles that may generate undesired "false" faults and some voltage spikes on the interlock input contacts generates the need for a hysteresis on the interlock level: this can be obtained by simply setting the interlock 2 intervention time to a few seconds (4s for example – i.e. 4000ms) in the following way:

MWG:51:4000\r

The previous settings do not become active until a 'MUP\r' (Module Update Parameters) command is sent to the power supply module and a '#AK\r' response has been received.

3.3 EEPROM Memory Mapping

Each DiRAC power supply unit has an on-board EEPROM memory that stores all information about calibration parameters, module identification, thresholds, interlock naming and configuration, etc.

Some of these fields can be user-defined and are extremely useful in order to exactly fit the power supply to the specific application.

EEPROM memory size is 256Kbits and was divided into two main different sections, each one consisting of 128Kbits:

- **FIELD** section;
- **VALUE** section.

This section division can be seen in **Figure 6**.

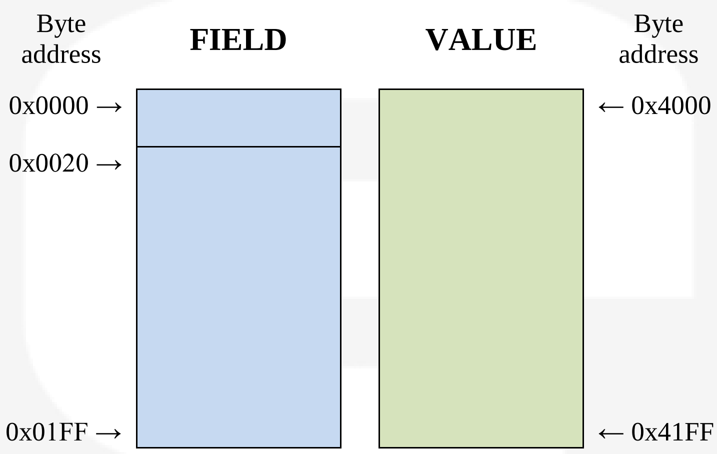


Figure 6: EEPROM memory sections

The EEPROM cell size is 0x20 bytes – i.e. 32 bytes – and, being the content stored in ASCII string format, the total string can contain 31 bytes + '\r' termination character.

Some EEPROM cells are password protected and can be unlocked using the 'PASSWORD' command (see the corresponding section for further details).

The password used to unlock the write-protected EEPROM cells of the modules is "PS-ADMIN".

The EEPROM **"value"** structure and the cell content description are presented in **Table 2**:

Cell #	Cell Caption	Description
0	c_0I_set	Zero-order current calibration coefficient
1	c_1I_set	1st-order current calibration coefficient
2	c_2I_set	2nd-order current calibration coefficient
3	c_3I_set	3rd-order current calibration coefficient
4	I_{max}	Maximum settable current set-point
5	c_0V_read	Zero-order voltage calibration coefficient
6	c_1V_read	1st-order voltage calibration coefficient
7	c_2V_read	2nd-order voltage calibration coefficient
8	c_3V_read	3rd-order voltage calibration coefficient
9…12	*reserved*	-
13	K_P - proportional constant	PID regulator proportional gain
14	K_I - integral constant	PID regulator integrative gain
15	K_D - derivative constant	PID regulator derivative gain
16…17	*reserved*	-
18	Newton-Raphson Iterations	Number of iterations for inverse calibration
19	*reserved*	-
20	Max Heatsink Temperature	Maximum heatsink temperature
21	Max Transformer Temperature	Maximum transformer temperature
22	Serial Number	Module serial number
23 … 25	*reserved*	-
26	Calibration Date	Date of last calibration
27	Identification	Module identification name
28 … 29	*reserved*	-
30	Slew Rate [A/s]	Module slew rate value
31	Earth Current Limit [A]	Maximum earth leakage current limit
32	Earth Current Gain	Earth current circuit gain value
33 … 36	*reserved*	-
37	Regulation fault threshold [A]	Maximum allowable regulation fault current
38	*reserved*	-
39	Ripple fault threshold [A]	Maximum allowable current ripple
40 … 46	*reserved*	-
47	*reserved*	-
48	Interlock Enable/Disable Mask	Enabling/disabling external interlocks
49	Interlock Activation State Mask	Definition of external interlocks active state
50	Interlock 1 Intervention Time (ms)	Intervention time for interlock 1
51	Interlock 2 Intervention Time (ms)	Intervention time for interlock 2
52	Interlock 3 Intervention Time (ms)	Intervention time for interlock 3

53	Interlock 4 Intervention Time (ms)	Intervention time for interlock 4
54…59	*reserved*	-
60	Time before regulation check [s]	Time before the regulation check starts [s]
61	Regulation calc window size [s]	Window size for regulation calculation [s]
62…64	*reserved*	-
65	Time before ripple check [s]	Time before the ripple regulation starts [s]
66	Ripple calc window size [s]	Window size for ripple calculation [s]

Table 2: EEPROM "Value" section

Please note that:

- cells marked in **blue** are password-protected;
- cells marked in **green** are not accessible by a standard user (factory-reserved).

All settable parameters need to be updated in order to take immediate effect on the module operation: a 'MUP\r' command needs to be sent to the DiRAC module after all parameters have been set by 'MWG' commands.

The EEPROM **"field"** structure and the cell content description are presented in **Table 3**:

Cell #	Cell Caption	Description
0 … 49	*reserved*	-
50	Interlock 1 identification	Interlock 1 identification name/string
51	Interlock 2 identification	Interlock 2 identification name/string
52	Interlock 3 identification	Interlock 3 identification name/string
53	Interlock 4 identification	Interlock 4 identification name/string

Table 3: EEPROM "Field" section

Please note that cells marked in **blue** are password-protected and need to be unlocked in order to write their content.

Please refer to **Table 2** and **Table 3** to write values and fields to configure correctly the DiRAC power supply unit and note that the commands to be used are:

- 'MWG' command to write the respective "value" cell content;
- 'MWF' command to write the respective "field" cell content.

The power supply controller automatically handles EEPROM addresses and "value" and "field" cell sections so that the MWF and MWG commands are almost transparent to the users and there is no need to write complicated cell addresses.

Example: suppose that the proportional term value – K_p – of the internal PID digital regulator has to be changed to 0.15. Referring to **Table 2**, this value is not password protected and it is placed at "value" section cell number 13.

The following command needs to be sent to the A3660BS module:

MWG:13:0.15\r

and should receive an acknowledgment reply from the power supply – i.e. '#AK\r'. Now, the value 0.15 it is stored in the "value" cell number 13 (which is the cell 0x41A0 since the "value" section offset is equal to 0x4000 bytes and each cell length is 0x20 byte). In order to make the module apply the value K_p = 0.15 to its internal regulator, a 'MUP\r' command has to be sent. The changing on the PID regulator parameters should in addition take effect only with the module output OFF.

3.3.1 "Value" Section Cells

Herein, in order to correctly configure and check the power supply operation, a brief description of the "value" section user-definable cells is presented:

- $\mathbf{I_{max}}$ – *cell 4*: the value contained in this cell defines the maximum current [A] that a user can set to the DiRAC power supply unit. This value need to be included between a lower limit 0A and [(rated output current) + 0.1]A;

- $\mathbf{K_P}$ – *cell 13*: this value is the proportional gain coefficient of the internal digital PID regulator;

- $\mathbf{K_I}$ – *cell 14*: this value is the integral gain coefficient of the internal digital PID regulator;

- $\mathbf{K_D}$ – *cell 15*: this value is the derivative gain coefficient of the internal digital PID regulator;

- **Max Heatsink Temperature** – *cell 20*: this value [°C] defines the temperature threshold above which the power supply generates an over-temperature fault condition. The temperature is directly measured in several different places inside the power unit and the maximum value among all these measured temperatures is taken into account;

- **Max Transformers Temperature** – *cell 21*: this value [°C] defines the temperature threshold above which the power supply generates an over-temperature fault condition. The temperature is measured on the power transformers;

- **Identification** – *cell 27*: this value, a string, defines the DiRAC module identification name (and can be read with the 'MRID\r' command);

- **Slew Rate** – *cell 30*: this value [A/s] determines the slew-rate value of the power supply. The module ramps, using the command 'MRM\r', at a defined set-point with this pre-defined value of slew-rate.

- **Earth Current Limit** – *cell 31*: this value [A] defines the maximum value allowable for the earth leakage current before generating a fault condition and disabling the power stage, thus generating a fault condition;

- **Regulation Fault Threshold** – *cell 37*: this value [A] defines the maximum allowable value, calculated as the difference from the actual output current set-point, before generating a fault condition;

- **Ripple Fault Threshold** – *cell 39*: this value [A] defines the maximum allowable value, calculated as the peak-to-peak output current ripple, before generating a fault condition;

- **Interlock Enable/Disable Mask**– *cell 48*: this cell contains and defines the hexadecimal ASCII number that represents the binary mask for the individual setting of interlocks from 1 to 4 (see "Interlocks Enabling/Disabling" for further information);

- **Interlock Activation State Mask**– *cell 49*: this cell contains and defines the hexadecimal ASCII number that represents the binary mask for the individual setting of activation state of interlocks from 1 to 4 (see "Interlocks Activation State" for further information);

- **Interlock 1 to 4 Intervention Time** – *cell 50 to 53*: these cells contain the values of the interlock intervention times in [ms] (see "Interlocks Intervention Time" for further information).

3.4 Status Register

Each DiRAC power supply unit has an internal 32-bit status register that contains all useful information about the power supply operation; this register is updated in real-time and it is always accessible by the user via the remote connection.

The internal status register structure is presented in **Table 4** (bit 31 is the MSB and bit 0 the LSB):

Status bit	Cell Caption
31	FAN FAIL WARNING
30	DCCT FAULT
29	OPEN LOOP OPERATION
28	EEPROM. READ WARNING
27 … 20	*reserved*
19 … 16	EXTERNAL INTERLOCKS [4…1]
15	RIPPLE FAULT
14	WAVEFORM EXECUTION FLAG

13	TURNING OFF
12	RAMP EXECUTION FLAG
11	REGULATOR FAULT
10	GROUND CURRENT
9	MAINS NOT OK
8	TRANSFORMER OVER-TEMPERATURE
7	INTERNAL OVER-TEMPERATURE
6	CROWBAR
5 … 4	*reserved*
3	LOCAL
2	WARNING
1	FAULT
0	MODULE ON

Table 4: 32-bit internal status register

The status register value can be directly read by users using the 'MST\r' command. The returned item is a 4-digit hexadecimal ASCII string, corresponding to the equivalent status register. A brief description of all the binary flags is here presented:

- **Module ON** – *bit 0*: this bit is set if the module is enabled and correctly regulating output current;

- **Fault** – *bit 1*: this bit is set if the module has experienced a fault – e.g. generated by an external interlock or an internal protection trip – and the status register has not been reset;

- **Warning** – *bit 2*: this bit is set if the module is in a "warning" condition (it is a logical or of all warning bits) – i.e. one of the cooling fans stopped working – this bit is set in conjunction with *bit 31 (fan fail warning).* Please note that the setting of this bit just gives an indication to the users that a fan is not correctly working and needs to be replaced (the module continues to work): the over-temperature faults still protect the DiRAC from damages from over-heating;

- . The warning condition are:
- *bit 31 (fan fail warning)* one of the cooling fans stopped working. Please note that the setting of this bit just gives an indication to the users that a fan is not correctly working and needs to be replaced (the module continues to work): the over-temperature faults still protect the DiRAC from damages from over-heating
- *bit 28 (EEPROM read warning)* this bit is set when a parameter is not read correctly from the EEPROM memory; in this case a default value is used for the firmware execution. To clear this warning it's necessary to check the EEPROM content and reload the parameters with the command 'MUP'.
- *bit 27 (Xport Timeout warning)* this bit is set when the MAC address is not correctly read from the Xport device. This warning does not

- **Local** – *bit 3*: this bit is set when the DiRAC is set to work in LOCAL mode, while this bit is cleared – i.e. set to ‘0’ – when working in REMOTE mode;

- **Crowbar** – *bit 6*: this bit is set when the voltage at the output terminals of the module triggers the crowbar protection (see “Internal Protections” section for further details). <u>This bit is also set when a *kill* signal from the external interlock 1, only if used in **HW** mode, had taken place.</u> The setting of this bit implies the simultaneous setting of the fault bit;

- **Internal Over-Temperature** – *bit 7*: this bit is set when the internal heatsink over-temperature condition has been experienced. The value that makes this fault trip is the maximum between the various ones measured inside the DiRAC unit. The setting of this bit implies the simultaneous setting of the fault bit;

- **Transformer Over-Temperature** – *bit 8*: this bit is set when the internal transformers over-temperature condition has been experienced. The value that makes this fault trip is the maximum between the various ones measured inside the DiRAC unit. The setting of this bit implies the simultaneous setting of the fault bit;

- **Mains NOT OK** – *bit 9*: this bit is set when the AC mains have experienced a fault – e.g. a phase loss, phase under-voltage or simply the front circuit breaker in “0” position. As in other cases, the setting of this bit implies the simultaneous setting of the fault bit;

- **Ground Current** – *bit 10*: this bit is set when a fault generated by an excessive leakage current to ground has been experienced. The setting of this bit implies the simultaneous setting of the fault bit;

- **Regulator Fault** – *bit 11*: this bit is set when a regulation fault is experienced. The setting of this bit implies the simultaneous setting of the fault bit;

- **Ramp Execution Flag** – *bit 12*: this bit is set when the DiRAC module is performing a ramp to a new set-point. After the ramp is finished, and the new set-point is reached, this flag is cleared;

- **Turning Off** – *bit 13*: this bit is set while the DiRAC module is turning off. The DiRAC power supply module, before disabling the output power stage, ramp down to 0A (zero) with a factory-defined slew-rate of 100A/s.

- **Waveform Execution Flag** – *bit 14*: this bit is set when the DiRAC module is performing a current waveform (see “Waveform Execution” section for further details);

- **Ripple Fault** – *bit 15*: this bit is set when an excessive current ripple on the output current is measured by the internal logic. The setting of this bit implies the simultaneous setting of the fault bit;

- **External Interlocks** – *bit 16 … 19*: these bits are set when the corresponding enabled external interlocks trip. These bits do not give any information about the

activation state of the interlock signals. The setting of anyone of these bits implies the simultaneous setting of the fault bit;

- **EEPROM parameters read warning** – *bit 28*: this bit is set when a parameter is not read correctly from the EEPROM memory; in this case the default value is used for the firmware execution. To clear this warning it is necessary to fix the EEPROM content and reload the parameters with the 'MUP' command.

- **Open Loop Operation** – *bit 29*: this bit is set when the A3660BS module works in *open-loop mode*. This mode is debugging and testing feature and it allows to set the duty cycle of the module from 0.07 – i.e. 7% – to 0.935 – i.e. 93.5%;

- **DCCT Fault** – *bit 30*: this bit is set when the internal DCCT, used for output current control, has experienced a fault. The setting of this bit implies the simultaneous setting of the fault bit;

- **Fan Fail Warning** – *bit 31*: this bit is set when at least one of the cooling fans installed on the DiRAC module is not correctly working. The setting of this bit is just an "indication" of the DiRAC module needing maintenance and implies the simultaneous setting of *bit 2 – "Warning"* but does not turn neither off the module nor sets a fault condition.

4. Local Control

This chapter describes the local control functionalities that are provided on each DiRAC power supply module and some useful information on how to use it.

Each DiRAC module can be operated independently in LOCAL or REMOTE mode: the switching between the two modes of operations can be set by the on-module encoder and its embedded menus.

After completing this operation, there should an evidence of the power supply being in the desired LOCAL mode: a black "L" character, surrounded by a red rectangle, appears on the upper-left angle of the display installed in the crate (an "R" character is displayed on the same angle when working in REMOTE mode).

The status of the module – e.g. LOCAL / REMOTE – on power-up is stored and recalled from the module internal memory so that each DiRAC unit powers up in the same state it was when it had been powered down.

4.1 Encoder

Each A3660BS module can be controlled by means of the rotary encoder placed on its front panel.This encoder allows two basic actions:

- **clockwise** (CW) and **counter-clockwise** (CCW) **rotation** in order to change selected menu lines or numbers;
- **pushing** in order to enter sub-menus or to confirm.

The combination of the cited actions allows browsing the power supply menus to read or set desired information and parameters.

4.2 Colour Display

The embedded colour display allows users to visualize information about the DiRAC power supply status and to control the unit in order to use it locally (it also allows switching to REMOTE mode operation). Screens and pages of the display can be changed from the encoder through user friendly menus and sub-menus.

4.2.1 *Power-up* Page

The DiRAC, upon power-up or power-cycling, should display a loading screen for a few seconds (see **Figure 7**), meaning that the power supply is correctly initializing and loading internal parameters.

Figure 7: *Power-up* display screen

After the initialization is done and internal parameters are correctly loaded, the fans should start rotating at a minimum speed level and the DiRAC display module should go to his "Home Page" screen.

4.2.2 Home (*Monitor*) Page

The DiRAC home page screen is the first loaded page upon power-up or power-cycling of the module, it is shown in **Figure 8**, and contains information on:

- the module LOCAL/REMOTE state;
- the DiRAC power supply unit identification name (content of EEPROM "value" cell 27);
- output current readback value [A], with 1mA resolution;
- output voltage readback value [V], with 10mV resolution;
- output active power readback value [W], with 100mV resolution;
- status of the power supply.

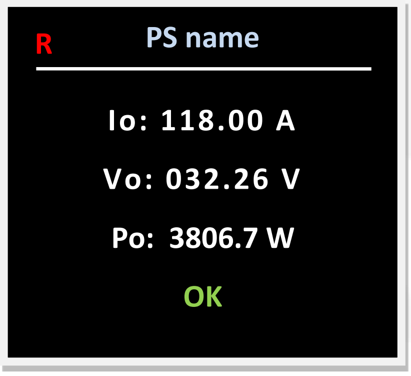


Figure 8: *Home Page* screen

The status indicator of the power supply – e.g. OK in the previous figure – is continuously blinking as it is updated (every 200 ms) and gives an indication on whether the module is operating correctly or not.

If the module has experienced one or more faults – e.g. interlock intervention, over-temperature conditions, etc. – the home page screen would display a list of all the faults, presenting them in an alternate way, one after the other.

The power supply latches on every fault recognized by the internal logic so that every type of fault is recorded: this means that the first fault happening does not ban the other ones to be recorded so that, giving users more information, permits a better investigation on the fault cause evaluation.

For example, if the module has experienced a regulator fault and a crowbar protection intervention, the home page bottom part of the screen will switch between the red strings "REG FAULT" and "CROWBAR".

If the module it is not turned on and the output is disabled, the home page screen should look like in **Figure 9**:

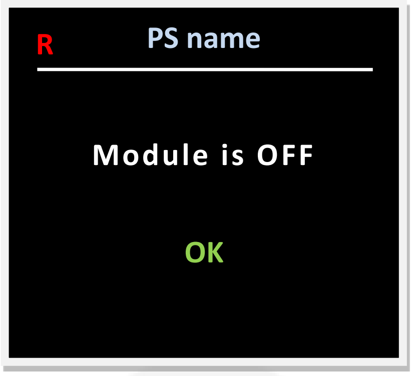


Figure 9: *Home Page* screen with module OFF

Please push the encoder button in order to access the Menu Page, thus exiting the Home Page menu.

4.2.3 Menu Page

The menu page is reachable by clicking the encoder button while being in the home page. Through this page the users have access to all the necessary setting/monitoring functions and sub-menus of the power supply.

The first screen shown in the Menu Page is shown in **Figure 10**:

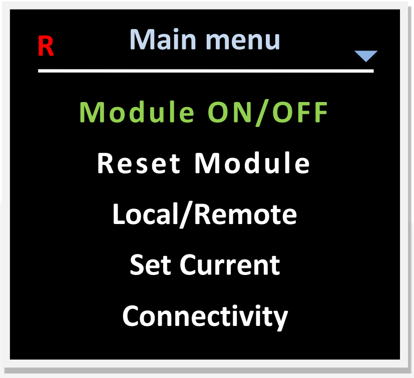


Figure 10: *Menu Page* screen

The accessible sub-menus from this page are herein listed (note that the selected sub-menu is lightened in green color):

- Module ON/OFF;
- Reset Module;
- Local/Remote
- Set Current;
- Connectivity;
- Global Stats;
- Exit.

A set of two blue arrows (one pointing upward and the other one downward) are shown in the upper right corner of this page in order to indicate the presence of additional sub-menu voices in the selected direction. Users can simply browse through this menu by rotating the encoder (a CW rotation makes the selection going downward in the menu while a CCW one in the opposite direction).

The selection of Module ON/OFF, Reset Module or Local/Remote has an immediate effect on the DiRAC power supply unit.

The Set Current, Connectivity or Global Stats selection gives access to their respective sub-menus while the Exit selection brings users back to the Home menu.

The selection of the last line of this menu – i.e. Exit – takes the users back to the Home (*Monitor*) Page.

Example: by clicking the Module ON/OFF line the module, if working in LOCAL mode and into correct operation (i.e. no faults), it should change its output condition – i.e. turns on if it was off and vice versa.

4.2.3.1 *Module ON/OFF*

The Module ON/OFF choice on the main menu allows users to change the DiRAC power supply status from ON to OFF and vice versa.

The DiRAC module obviously can be turned on only if it is not experiencing a fault condition (or a fault condition has been already reset) and it is working in LOCAL mode.

4.2.3.2 *Reset Module*

The Reset Module selection on the Main Menu allows users to reset fault conditions on the power supply unit. The reset takes effect only if the module is working in LOCAL mode.

4.2.3.3 *Local/Remote*

The Local/Remote choice on the main menu allows users to change the DiRAC power supply unit status from LOCAL operation to REMOTE and vice versa.

The actual status can be continuously monitored by the "L" or "R" letter on the upper-left corner of the display.

4.2.4 Set Current Page

The "Set Current" page allows users to locally set the current setpoint of the power supply module.

From this page it is also possible to check the actual module output current, indicated as "Read current (A)".

In order to perform the current setting operation it is necessary for the module to be in the LOCAL mode (indicated by a black "L" in a red frame in the upper left corner of the display), as shown in **Figure 11**:

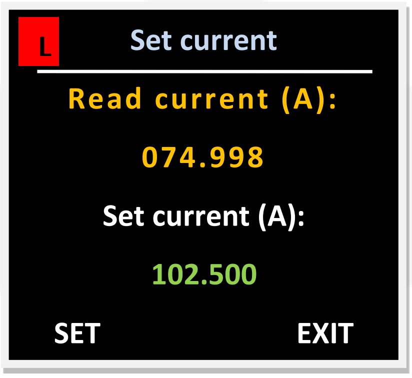


Figure 11: *Set Current* screen

The "Set" text in the bottom left corner of the display needs to be clicked on in order to make the new current setpoint take effect. The power supply unit will reach the new setpoint by ramping with the predefined slew rate, which can be checked on the "Connectivity" page of the menu.

By clicking the "Exit" text on the bottom right corner the user can return to the Menu page.

4.2.5 Connectivity Page

The "Connectivity" page allows users to check the module MAC (*Media Access Control*) address and the IP address as well as also setting the second one.

The DiRAC power supply IP address can be easily changed from this panel by selecting the new address with the local encoder in the screen shown in **Figure 12**:

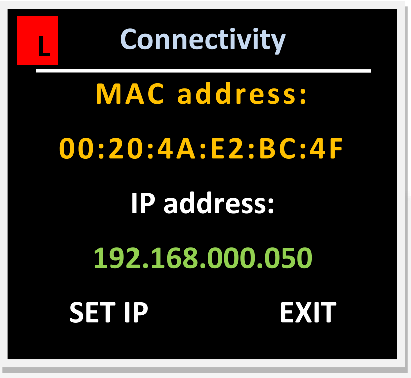


Figure 12: *Connectivity* screen

After clicking the "Set" text the power supply should display a window - shown in **Figure 13** – showing to the users that the new IP address is configuring. The set operation can be performed only by setting the module to LOCAL mode.

Figure 13: screenshot shown when updating IP address

It is very important to notice that once the "Set" text has been clicked, the user can remotely communicate and get control of the power supply again only by opening a new TCP socket to the IP that has just been set.

4.2.6 Global Stats Page

The "Global Stats" page allows users to check and monitor some of the ancillary features of the DiRAC power supply module as the installed firmware version, slew-rate settings, etc.

An example on how the Global Stats page of the module is presented can be seen in **Figure 14**:

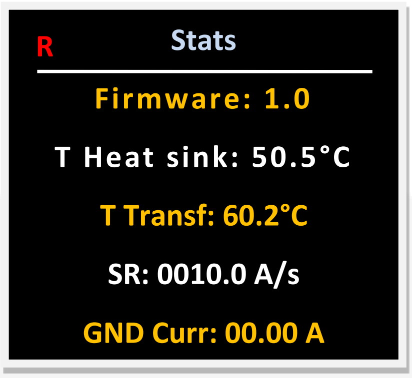


Figure 14: *Global Stats* screen

This page can be browsed by rotating the encoder and can be exited at any moment by clicking on the same encoder pushbutton (this action sends the user back to the Menu Page).

The features that can be displayed on this menu are the following:

- **Firmware:** the installed DiRAC firmware version;
- **T Heatsink:** the maximum measured heatsink temperature [°C], please note that several temperatures are measured on the board;
- **T Transf**: the maximum measured transformer temperature [°C];
- **SR:** the defined value for the slew-rate [A/s];
- **GND Curr:** the measured ground leakage current [A];

5. Remote Control

Any DiRAC power supply unit can be also remotely controlled via a standard Ethernet 10/100 link using a predefined set of commands.

After setting the DiRAC module to REMOTE operation, there should be an evidence of the power supply system being in this mode: a red “R” character should appear on the upper-left angle of the power supply display (an “L” character is displayed on the same angle when working in LOCAL mode).

The status of the module – e.g. LOCAL / REMOTE – on power-up is stored and recalled from the module internal memory so that each DiRAC unit powers up in the same state it was when it had been powered down.

5.1 Preliminary Information

In order to ensure a correct communication with a DiRAC power module, the following rules have to be pointed out:

- commands to the DiRAC power supply must be sent with a **‘\r’** (carriage return, 0x0D hexadecimal number) termination character;
- replies from the DiRAC power supply also have a **‘\r’** (carriage return, 0x0D hexadecimal number) termination character.

A complete list of commands (except for reserved commands) is herein presented and an overview for each command syntax and functionality follows.

The extreme configurability of this power supply leads to a very widespread command list, thus typical users may only need a small set of commands in order to run the DiRAC unit in a satisfying way.

5.2 List of Commands

The user-available commands, as well as a brief description and their read or write functionality, are summarized in the following table:

Command	Description	Read/Write
HWRESET	Performs an hardware reset of the unit	W
FDB	Feedback command	R/W
MAC	Read MAC and IP addresses of the module	R
MGC	Read ground leakage current value	R
MGLST	Read the main values and status of the module	R
MOFF	Turn the module OFF	W
MON	Turn the module ON	W
MRESET	Reset the module status register	W
MRF	Read selected EEPROM "field" cell	R
MRG	Read selected EEPROM "value" cell	R
MRI	Read output current value	R
MRID	Read module identification	R
MRM	Set output current value (ramp)	W
MRT	Read heatsink temperature	R
MRTS	Read transformer temperature	R
MRV	Read output voltage value	R
MRW	Read estimated active output power value	R
MSP	Read last stored output current setpoint	R
MSR	Read or write slew-rate value	R/W
MST	Read module internal status register	R
MUP	Update all EEPROM parameters	W
MWAVE	Set waveform total number of points	W
MWAVEP	Set waveform single point	W
MWAVER	Read stored waveform points	R
MWAVESTART	Start waveform execution	W
MWAVESTOP	Stop waveform execution	W
MWF	Write selected EEPROM "field" cell	W

MWG	Write selected EEPROM "value" cell	W
MWI	Set output current value (no ramp)	W
PASSWORD	Write password to unlock password-protected cells	W
SIP	Set module IP address	W
VER	Read module model and installed firmware versions	R

Table 5: DiRAC module Command List

It is important to notice that some commands are write-only commands (e.g. MRM to set output current) and some others are read-only commands (e.g. MRI to read output current value).

The only command that allows reading and setting is the MSR command, which reads or sets the user-defined slew-rate for the power supply (see 'MSR Command' section for further details).

5.3 Commands Overview

The power supply controller replies every time that a termination character '\r' is received. Replies could have different behaviors:

- an acknowledgment '#AK\r' string is sent back in case of a correct setting command;
- a non-acknowledgment '#NAK\r' string is sent back in case of a wrong/unrecognized command or if the system is in local operation mode and a write command is sent to the controller (write commands are marked with a 'W' in **Error! Reference source not found.**);
- a standard reply, preceded by a '#' and followed by a '\r' character, is sent back as a response to a reading command.

A brief description for each command, in alphabetical order, is herein presented with some example annotations; the correct interpretation for these examples is as follows:

Command sent TO the power supply →

← **Reply FROM the power supply**

5.3.1 "FDB" Command

The 'FDB' command is a custom command that was especially implemented in order to minimize traffic on the Ethernet communication socket and it has a dedicated request/reply structure.

The feedback command syntax is as follows:

FDB:set_reg:i_set\r

where:

- *set_reg*: is the setting register of the power supply (8-bit wide);
- *i_set*: is the desired output current setpoint value [A].

The power supply reply, after a FDB command, it is in the following format:

#FDB:status_reg:i_set:i_read\r

where

- *status_reg*: is the 32-bit wide *status register* of the PS, formatted in an hexadecimal string; this status string has a fixed-length of 8-byte;
- *i_set*: is the string containing the output current desired setpoint value; string length is 9 bytes (i.e. 8 characters): sign + 3 integers + "." + 4 decimal digits (eg. 1,02A it is returned as +01.0200);
- *i_read*: is the output current readback string; its length is equal to 9 bytes: sign + 3 integers + "." + 4 decimal digits;

The *status_reg* structure is presented in the following table (and in section 3.4):

DiRAC Module Status Register (32-bit)	
Status bit	**Cell Caption**
31	FAN FAIL WARNING
30	DCCT FAULT
29	OPEN LOOP OPERATION
28	EEPROM PARAM. READ WARNING
27 … 20	*reserved*
19 … 16	EXTERNAL INTERLOCKS [4…1]
15	RIPPLE FAULT
14	WAVEFORM EXECUTION FLAG
13	TURNING OFF

12	RAMP EXECUTION FLAG
11	REGULATOR FAULT
10	GROUND CURRENT
9	MAINS NOT OK
8	TRANSFORMER OVER-TEMPERATURE
7	INTERNAL OVER-TEMPERATURE
6	CROWBAR
5 … 4	*reserved*
3	LOCAL
2	WARNING
1	FAULT
0	MODULE ON

The *set_reg* structure, in order to set the desired behaviour, must be interpreted as follows:

FDB command register (8bit):	Bit Function:
Bit 7	**BYPASS COMMAND**
Bit 6	**ON/OFF**
Bit 5	**RESET**
Bit 4	**RAMP**
Bit 3…0	***don't care***

Example:

Suppose that the DiRAC power unit is ON and it is regulating at 85.0000A output current. The user sends the following command to the DiRAC:

FDB:58:83.2453\r →

← #FDB:00001001:+083.2453:+085.0000\r

After sending the FDB command, the PS turns on (it was already ON) and sets its current to 83.2453A reaching this setpoint with a ramp (defined by the slew rate value stored in the PS non-volatile memory).

The entire reply from the power supply, referred to the format just presented, can be interpreted as follows:

- *Module is ON;*
- *Ramp is executing (Ramp execution flag);*
- *actual output current value is 85.0000A;*
- *the new set-point is 83.2453A.*

5.3.2 "HWRESET" Command

The 'HWRESET\r' command performs a complete reset of the hardware and firmware of the on-board FPGA, thus re-initializing the entire DiRAC module control electronics.

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the module is in LOCAL mode;
- the module is ON (it is necessary to turn the module OFF first in order to perform a remote hardware reset).

Examples:

HWRESET example with the module in LOCAL mode:

HWRESET\r →

← #NAK\r

HWRESET example with the module in REMOTE mode:

HWRESET\r →

← #AK\r

It is important to notice that the DiRAC power supply unit replies with an acknowledgment command "#AK\r" before resetting the internal hardware and firmware. After reset, the communication to the power supply module can be lost for a few seconds as a consequence of re-initialization.

5.3.3 "MAC" Command

The 'MAC\r' command returns both the MAC address and IP address of the connected A3660BS power supply in the following form:

#MAC:mac_addr:ip_addr\r

where:
- *mac_addr* is the MAC address of the module;
- *ip_addr* is the IP address of the module.

The MAC command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MAC example:

MAC\r →

← #MAC:00204AD4ED5B:192.168.0.10\r

5.3.4 “MGC” Command

The ‘MGC\r’ command returns the readback value of the actual ground leakage current of the DiRAC power supply unit in the following form:

#MGC:value\r

where:

- *value* is the earth current value readback [A].

If a “*Ground current*” fault occurs, the MGC command will return the ground leakage current which caused the fault. The MGC command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MGC example for a 120mA earth leakage current:

MGC\r →

← #MGC:0.12\r

5.3.5 "MGLST" Command

The 'MGLST\r' command is a general purpose reading command that returns some useful readback values as well as the power supply global status.

Replies from the DiRAC module are in the following form:

#MGLST:i_out:v_out:status:i_gnd:i_set\r

where:

- *i_out* is the output current value readback [A];
- *v_out* is the output voltage value readback [V];
- *status* is the ASCII representation, composed by eight hexadecimal digits, of power supply 32-bit status register;
- *i_gnd* is the ground leakage current readback [A];
- *i_set* is the last stored output current setpoint [A].

The MGLST command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MGLST example for a DiRAC power supply module set to +73.0355A:

MGLST\r →

← #MGLST:+73.0356:5.4321:0003:0.00:+13.0355\r

5.3.6 "MOFF" Command

The 'MOFF\r' command is intended to turn off the DiRAC unit power section, thus not allowing any current to flow through the output current terminals.

The 'MOFF\' command automatically sets output current to 0A (zero) with a factory default slew-rate before disabling the power part; this is done in order to avoid voltage overshoots - that would be anyway smoothed and limited by the crowbar and over-voltage clamping protections - especially for high currents and strongly inductive loads.

Replies from the DiRAC power supply to a 'MOFF\r' command are in the form '#AK\r' or '#NAK\r'; the '#NAK\r' reply is obtained if:

- the module is in LOCAL mode;

Sending a 'MOFF\r' command when the module output is already disabled generates an acknowledgment response – i.e. '#AK\r'.

Examples:

MOFF example when the DiRAC module output is already disabled:

MOFF\r →

← #AK\r

MOFF example when the DiRAC power supply unit is in LOCAL mode:

MOFF\r →

← #NAK\r

MOFF example when the DiRAC module is ON and sourcing/sinking current:

MOFF\r →

← #AK\r

5.3.7 "MON" Command

The 'MON\r' command is intended to turn on the DiRAC power section, thus enabling the output current terminals and allowing the power supply to regulate and feed current to the connected load.

After the reception of an 'MON\' command, the power supply automatically sets output current to 0A (zero) when enabling the output.

Replies from the DiRAC module to a 'MOFF\r' command are in the form '#AK\r' – when the command is correctly executed - or '#NAK\r'. The '#NAK\r' reply is obtained if:

- the power supply is in LOCAL mode;
- the DiRAC module is in a FAULT condition (it is necessary to reset the status register after a generic fault condition in order to turn the power supply ON again - see command 'MRESET\r').

Sending a 'MON\r' command when the module output is already enabled generates an non-acknowledgment response – i.e. '#NAK\r'.

Examples:

MON example when no fault conditions are present:

MON\r →

← #AK\r

MON example when the DiRAC power unit is in LOCAL mode:

MON\r →

← #NAK\r

5.3.8 "MRESET" Command

The 'MRESET\r' command has to be used in order to perform a complete reset of the module status register: this is needed, for example, to re-enable the power supply output again after a fault condition has been fixed.

Reply from the DiRAC module is '#AK\r' if the module is set in REMOTE mode and "#NAK\r' if in LOCAL mode.

Examples:

MRESET example when DiRAC power unit is in LOCAL mode:

MRESET\r →

← #NAK\r

MRESET example when DiRAC power unit in REMOTE mode:

MRESET\r →

← #AK\r

5.3.9 "MRF" Command

The 'MRF\r' command returns the value stored in the "field" parameter of a desired EEPROM cell. The correct form for the reading request is as follows:

MRF:cell_num\r

where:

- *cell_num* is the EEPROM cell number.

The on-board EEPROM memory - used to store module information as calibration parameters, identification, thresholds – has 512 cells, so that *cell_num* is limited between 0 and 511; requests containing cell values exceeding these limits obtain a non-acknowledgment reply '#NAK\r'. The "field" section of the EEPROM is used to store interlocks identification names (cells 50 to 53); for more information on how to write parameters in the "field" area of the memory, please refer to "MWF Command" section.

Replies from the DiRAC power supply are in the following format:

cell_content\r

where:

- *cell_content* is the *cell_num* content in an ASCII representation.

The MRF command, being a reading command, returns a response in any module condition (e.g. local/remote); this reply is a "#NAK\r" also if the memory cell is empty.

Examples:

MRF example with cell_num out of limits:

MRF:539\r →

← #NAK\r

MRF example for a user-defined interlock-related cell (interlock 3):

MRF:52\r →

← THERMAL_SWITCH1\r

5.3.10 "MRG" Command

The 'MRG\r' command returns the value stored in the "value" parameter of a desired EEPROM cell. The correct form for the reading request is as follows:

MRG:cell_num\r

where:

- *cell_num* is the EEPROM cell number.

The on-board EEPROM memory - used to store module information as calibration parameters, identification, thresholds – has 512 cells, so that *cell_num* is limited between 0 and 511; requests containing cell values exceeding these limits obtain a non-acknowledgment reply '#NAK\r'.

A non-acknowledgment response – i.e. '#NAK\r' – is returned also if the field *cell_num* is empty.

The "value" section of the EEPROM is used to store calibration parameters, identification, thresholds, interlock information, etc. and other user-definable factors. For more information on how to write parameters in the "value" area of the memory, please refer to "MWG Command" section.

Replies from the DiRAC power supply unit are in the following format:

cell_content\r

where:

- *cell_content* is the *cell_num* content in an ASCII representation.

The MRG command, being a reading command, returns a response in any module condition (e.g. local/remote); this reply is "#NAK\r" also if the memory cell is empty.

Examples:

MRG example with cell_num out of limits:

MRG:675\r →

← #NAK\r

MRG example for cell 31 (containing earth current threshold [A]):

MRG:31\r →

← 0.5\r

MRG example for cell 4 (containing the maximum settable current value [A]):

MRG:4\r →

← 82.524\r

5.3.11 "MRI" Command

The 'MRI\r' command returns the readback value of the power supply actual output current.

Current readback values have a 20-bit resolution (19-bit + sign) and they are presented with a 5-digit precision.

Replies from the power supply A3660BS to this command are in the following form:

#MRI:*value*\r

where:

- *value* is the output current value readback [A].

The MRI command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRI example when the module is OFF:

MRI\r →

← #MRI:0.00150\r

MRI example when the DiRAC power module is ON and regulating:

MRI\r →

← #MRI:+48.34563\r

5.3.12 "MRID" Command

The 'MRID\r' command returns the DiRAC power supply unit identification name as a string.

The reply from the power supply contains the value stored in cell 27 of the module EEPROM and it assumes the following format:

#MRID:module_id\r

where:

- *module_id* is the module identification stored in non-volatile memory, as an ASCII string.

This command is equivalent to the 'MRG:27\r' command, being the cited cell content the user-selected module identification name.

The MRID command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRID example with the module identification "ChicaneMag5.2":

MRID\r →

← #MRID:CHICANEMAG5.2\r

5.3.13 "MRM" Command

The 'MRM' command is used to set the value of the desired output current set-point:

MRM:value\r

where:

- *value* is the output current desired set-point [A].

The difference between the 'MWI\r' command and the 'MRM\r' command is that the first one generates a direct change in output current characterized by the PID regulator parameters (slew-rate value is discarded and the command is ideally suited for small output current changes and feedback purposes) while the second one makes the power supply go from the previous to the actual current value performing a ramp, defined by a slew-rate (in A/s) stored in the EEPROM cell 30.

The DiRAC power supply unit responds with acknowledgment command '#AK\r' if the value is correctly set and with a '#NAK\r' if:

- the set *value* is out-of-range (the maximum settable current value is user-defined and stored in EEPROM cell 4);
- the power supply is OFF (it is necessary to turn the module ON first);
- the power supply is in LOCAL mode.

If the MRM command is executed during the ramp or waveform generation, the ramp/waveform execution will be stopped and the new ramp will be performed to the new set-point.

Examples:

MRM example with the DiRAC power supply unit in OFF state:

MRM:113.872\r →

← #NAK\r

MRM example with the DiRAC power supply unit turned ON and not ramping nor performing a waveform:

MRM:113.872\r →

← #AK\r

5.3.14 "MRT" Command

The 'MRT\r' command returns the maximum value of the temperatures among the ones measured on the internal heatsinks.

Even if the internal ADCs have a 16-bit resolution, this value is presented to the user with a 0.1 °C (= 0.1 K) resolution.

The module internal logic compares the temperature values measured and then selects the maximum of these values, thus giving an indication on the "hottest" part of the DiRAC heatsink.

Replies from the DiRAC power supply to this command are in the following form:

#MRT:value\r

where:

- *value* is the temperature value [°C = Celsius] measured on the internal heatsink.

The MRT command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRT example:

MRT\r →

← #MRT:42.1\r

5.3.15 "MRTS" Command

The 'MRTS\r' command returns the maximum value of the temperatures among the ones measured on the internal transformers.

Even if the internal ADCs have a 16-bit resolution, this value is presented to the user with a 0.1 °C (= 0.1 K) resolution.

The module internal logic compares the temperature values measured and then selects the maximum of these values, thus giving an indication on the "hottest" part of the DiRAC transformers.

Replies from the DiRAC power supply to this command are in the following form:

#MRTS:value\r

where:

- *value* is the temperature value [°C = Celsius] measured on the internal transformers.

The MRTS command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRTT example:

MRTS\r →

← #MRTS:42.1\r

5.3.16 "MRV" Command

The 'MRV\r' command returns the readback value of the power supply actual output voltage, measured at the DiRAC output terminals.

As for the output current, voltage readback values have a 20-bit resolution (19-bit + sign) and they are presented with a 5-digit precision.

Replies from the DiRAC power supply unit to this command are in the following form:

#MRV:value\r

where:

- *value* is the output voltage readback [V], measured at the module output terminals.

The MRV command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRV example when the module is OFF:

MRV\r →

← #MRV:+0.00012\r

MRV example when the module is ON and regulating output voltage:

MRV\r →

← #MRV:+29.54563\r

5.3.17 "MRW" Command

The 'MRW\r' command returns the actual value of the estimated active power supplied to the connected load.

This estimation, being computed as the product of the output voltage and the output current readback values, has the same 20-bit resolution and it is presented with a 5-digit precision.

Replies from the DiRAC power supply unit to this command are in the following form:

#MRW:value\r

where:

- *value* is the output active power readback [W], estimated as the product of output voltage and output current readbacks.

The MRW command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MRW example when the power supply is OFF:

MRW\r →

← #MRW:-0.04532\r

MRW example when the power supply is ON and regulating output current:

MRW\r →

← #MRW:4322.72345\r

5.3.18 "MSP" Command

The 'MSP\r' command returns the value of the power supply last stored set-point current value.

Replies from the DiRAC power unit to this command are in the following form:

#MSP:value\r

where:

- *value* is the last stored output current set-point value [A].

The MSP command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MSP example when the module is OFF:

MSP\r →

← #MSP:+082.23456\r

5.3.19 "MSR" Command

The 'MSR' command it is the only read/write command for the DiRAC power unit and it allows reading and setting of the value of the slew rate, in A/s, of the power supply. The reading command is structured as follows:

MSR:?\r

and the related reply format is:

#MSR:value\r

where:

- *value* is actual slew-rate value for the power supply [A/s], that is the content of the EEPROM cell 30, with a 5-digit precision.

The value of the slew-rate can also be set, between lower limit of 0 A/s and upper limit of 1000 A/s, using the MSR command and adopting the following syntax:

MSR:set_value\r

where:

- *set_value* is desired slew-rate value [A/s].

The MSR setting command generates, upon reception, an acknowledgment – i.e. '#AK\r' - reply if the value is correctly set and with a '#NAK\r' if:

- the set *value* is incorrect (e.g. out of limits);
- the module is in LOCAL mode.

Examples:

MSR reading example:

MSR:?\r →

← #MSR:15.00000\r

MSR setting example with a value out of limits:

MSR:13007\r →

← #NAK\r

MSR setting example to a correct value:

MSR:88.6\r →

← #AK\r

5.3.20 "MST" Command

The 'MST\r' command returns the value of the power supply internal status register (32 bit).

Replies from the DiRAC power supply unit to this command are in the following format:

#MST:*value*\r

where:

- *value* is the ASCII representation of the internal status register value, composed by 8 hexadecimal digits, and corresponding to the 32-bit wide status register.

The MST command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

MST example with the DiRAC power supply ON, ramping and in LOCAL mode:

MST\r →

← #MST:01000009\r

5.3.21 "MUP" Command

The 'MUP\r' (Module UPdate) command performs an update of the DiRAC power supply actual parameters with the parameters read from the module EEPROM.

As an example, the MWF command updates only the content of the selected EEPROM field but not the corresponding DiRAC power unit parameters. In order to make the module update its parameters and so to make these changes take effect it is necessary to perform the 'MUP\r' command: this procedure is implemented not to apply wrong or undesired transmitted values *on-the-run*.

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the power supply is in LOCAL mode;
- the power supply is ON (it is necessary to shut-down the channel with MOFF command first).

Examples:

MUP example with the power supply OFF and in REMOTE mode:

MUP\r →

← #AK\r

MUP example with the power supply ON and/or in LOCAL mode:

MUP\r →

← #NAK\r

5.3.23 "SIP" Command

The 'SIP' command allows setting remotely the DiRAC power supply module IP address.

In order to set a new IP address to a module it is necessary to know the actual one (this is possible by checking the "Connectivity" menu on the local color display of the module or by using the DeviceInstaller® software that can be found at www.lantronix.com).

The correct format syntax for this command is:

SIP:ip_addr\r

where:

- *ip_addr* is desired new IP address for the connected module is formed by four decimal numbers (each ranging from 0 to 255) separated by dots;

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the DiRAC power unit is in LOCAL mode;
- the DiRAC power unit is ON (it is necessary to disable the output power with the MOFF command first for safety purposes);
- the sent IP address is incorrect.

Examples:

SIP example with a correct IP address:

SIP:192.168.0.55\r →

← #AK\r

After this command, the Ethernet module on the DiRAC power supply unit re-initializes and connection to the host is lost.

SIP example with the power supply unit in LOCAL mode:

SIP:192.168.0.55\r →

← #NAK\r

SIP example with an incorrect IP address:

SIP:192.168.0.324\r →

← #NAK\r

It is very important to notice that once the SIP command has been executed, the user can communicate and get control of the power supply again only by opening a new TCP socket with the IP address that has just been set.

5.3.24 "VER" Command

The 'VER\r' command returns information about the DiRAC power supply unit model and the currently installed firmware versions.

The response to a 'VER\r' command is in the following format:

#VER:DIRAC:Model:FPGA_ver\r

where:

- *Model* is the DiRAC power supply model
- *FPGA_ver* is the FPGA firmware version currently installed on the module.

Please note that you can keep firmware version up to date by checking for updates/upgrades on the website (www.caenels.com/caenels).

The VER command, being a reading command, returns a response in any module condition (e.g. local/remote).

Examples:

VER example:

VER\r →

← #VER:DIRAC:1.0\r

5.3.25 "MWAVE" Command

The 'MWAVE' has to be used to load current waveform points that can be subsequently executed; the DiRAC module has the capability of executing a pre-loaded waveform with a 1-ms update period (i.e. 1 kHz update rate).

The correct format for this command is as follows:

MWAVE:sample_num:sample_value\r

where:

- *sample_num* is sample number of the waveform, ranging from 0 – i.e. the first sample – to the last sample number, defined by (*tot_points* – 1) (see MWAVEP command for details);
- *sample_value* is the sample current set-point value [A].

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the DiRAC power supply unit is in LOCAL mode;
- the DiRAC power supply unit is executing a waveform;
- the *sample_num* value is greater than the one defined for the number of points of the pre-loaded waveform (by a MWAVEP command);
- the *sample_value* of the current is greater than the maximum value defined for the settable current (defined in EEPROM "value" cell #4).

Examples:

MWAVE correct example:

MWAVE:15:+46.32255\r →

← #AK\r

MWAVE example with a sample_num greater than the waveform length (MWAVEP):

MWAVE:15:+46.32255\r →

← #NAK\r

5.3.26 "MWAVEP" Command

The 'MWAVEP' command defines the maximum number of points – i.e. length – of a pre-loaded point-by-point current waveform.

The correct format for this command is as follows:

MWAVEP:tot_points\r

where:

- *tot_points* is the total number of points of the waveform (ranging from 0 – i.e. no-points – to 60000 – i.e. 60-second waveform).

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the total number of points *tot_points* is out of range;
- the DiRAC power unit is in LOCAL mode;
- the DiRAC power unit is executing a waveform.

Examples:

MWAVEP correct example:

MWAVEP:2000\r →

← #AK\r

MWAVEP example with the module performing a waveform:

MWAVEP:2000\r →

← #NAK\r

5.3.27 "MWAVER" Command

The 'MWAVER' command returns the value of the selected current waveform set-point sample.

The value returned by this command is the same one that was previously stored with a MWAVE command use.

The correct format for this command is as follows:

MWAVER:sample_num\r

where:

- *sample_num* is the index of the selected sample which value has to be returned.

The MWAVER command, being a reading command, returns a response in any module condition (e.g. local/remote) except if *sample_num* is over the defined range.

Replies from the DiRAC power supply unit are in the following format:

#MWAVER:value\r

where:

- *value* is the current value stored in the selected sample.

Examples:

MWAVER example for a correct request:

MWAVER:264\r →

← #MWAVER:42.45323\r

MWAVER example for a sample_num value out of range:

MWAVER:180000\r →

← #NAK\r

5.3.28 "MWAVESTART" Command

The 'MWAVESTART' command is used to make the DiRAC power supply execute the pre-defined loaded waveform.

The correct form format for this command is as follows:

MWAVESTART:cycles\r

where:

- *cycles* is the total number of periods that the waveform has to be executed (its period length can be defined using the MWAVEP command).

The powers supply can execute the current waveform for a fixed number of periods ranging from 1 to 1440 (equal to a 24-hour total execution time for a 60000 points waveform).

The infinite execution of the waveform is also possible and it is obtained by passing to power supply a -1value, so that:

'MWAVESTART:-1\r'

repeats the waveform for an INFINITE number of cycles

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated, as it is for the MRM command, when:

- the power unit is in LOCAL mode;
- the power unit is still performing a ramp (it is necessary to wait for the power supply to end the previous ramp) or it is performing a waveform;
- the power unit is OFF (it is necessary to turn it ON first);
- the number of cycles value is out-of-range – i.e. greater than 1440.

Examples:

MWAVESTART example with an excessive number of cycles:

MWAVESTART:1458\r →

← #NAK\r

MWAVESTART example that starts an infinite waveform:

MWAVESTART:-1\r →

← #AK\r

MWAVESTART example that repeats the waveform for 20 cycles:

MWAVESTART:20\r →

← #AK\r

5.3.29 "MWAVESTOP" Command

The 'MWAVESTOP\r' stops the execution of a running waveform (that was previously started with a MWAVESTART command).

This command immediately stops the execution of the stored current waveform that is running and ramps down current to 0A (zero) with a factory default slew-rate.

Replies from the DiRAC power supply unit are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated, as it is for the MRM command, when:

- the power supply unit is in LOCAL mode;
- the power supply unit is not executing a waveform;

Examples:

MWAVESTOP example when DiRAC unit is not performing a waveform or is in LOCAL mode:

MWAVESTOP\r →

← #NAK\r

MWAVESTOP example with a waveform running:

MWAVESTOP\r →

← #AK\r

5.3.30 "MWF" Command

The 'MWF' command lets users write a desired "field" item in a defined EEPROM cell.

The correct form format for this command is as follows:

MWF:cell_num:cell_content\r

where:

- *cell_num* is the EEPROM cell number;
- *cell_content* is the ASCII content to be written to the EEPROM cell *cell_num*.

The on-board EEPROM memory - used to store module information as calibration parameters, identification, thresholds and divided in two sections, "field" and "value" – has 512 cells, so that *cell_num* is limited between 0 and 511; writing operations containing cell values exceeding these limits obtain a non-acknowledgment reply '#NAK\r'.

This "field" section of the EEPROM is used to store descriptive items as interlocks identification names (cells 50 through 53).

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the DiRAC unit is in LOCAL mode;
- the cell number *cell_num* is out-of-range (negative or greater than 511);
- *cell_num* or *cell_content* are empty strings;
- the selected cell is password protected and password protection is not unlocked (see 'PASSWORD\r' command for further details).

Examples:

MWF example with the DiRAC unit in LOCAL mode:

MWF:52:INTERLOCK_A\r →

← #NAK\r

MWF correct example (after password is unlocked):

MWF:52:INTERLOCK_A\r →

← #AK\r

5.3.31 "MWG" Command

The 'MWG' command lets users write a desired "value" item in a defined EEPROM cell.

The correct form format for this command is as follows:

MWG:cell_num:cell_content\r

where:

- *cell_num* is the EEPROM cell number;
- *cell_content* is the ASCII content to be written to the EEPROM cell *cell_num*.

The on-board EEPROM memory - used to store module information as calibration parameters, identification, thresholds and divided in two sections, "field" and "value" – has 512 cells, so that *cell_num* is limited between 0 and 511; writing operations containing cell values exceeding these limits obtain a non-acknowledgment reply '#NAK\r'.

This "value" section of the EEPROM is used to store descriptive calibration parameters, identification, thresholds, etc. and some cells are password protected (see the "EEPROM Memory Mapping" section to check what cells are protected and what are not).

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated when:

- the DiRAC unit is in LOCAL mode;
- the cell number *cell_num* is out-of-range (negative or greater than 511);
- *cell_num* or *cell_content* are empty strings;
- the selected cell is password protected and password protection is not unlocked (see 'PASSWORD\r' command for further details).

Examples:

MWG example with the DiRAC module in LOCAL mode:

MWG:52:INTERLOCK_A\r →

← #NAK\r

MWG example of a correct "write" operation (cell 13 is not password-protected):

MWG:13:0.055\r →

← #AK\r

MWG example (cell 1 is password-protected and password not unlocked):

MWG:1:15.234\r →

← #NAK\r

5.3.33 "MWI" Command

The 'MWI' command can be used to set the output current value and it is used when fast set-point changes are needed.

The use of this command is alternative to the MRM (Module RaMping): the power supply reaches the desired output current value just using the PID regulator parameters, without ramping with the pre-defined slew rate to the new set-point.

This command is usually needed when running feedback-related applications and **ONLY** for small changes in the output current.

The correct format for this command is as follows:

MWI:value\r

where:

- *value* is the desired output current value [A].

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated, as it is for the MRM command, when:

- the set *value* is out-of-range (the maximum settable current value is user-defined and stored in EEPROM cell 4);
- the power unit is OFF (it is necessary to turn the module ON first);
- the power unit is in LOCAL mode.

If the MWI command is executed during the ramp or waveform generation, the ramp/waveform execution will be stopped and the new set-point will be applied.

Examples:

MWI example with the module OFF:

MWI:48.55679\r →

← #NAK\r

MWI example with the module ON and already regulating:

MWI:13.50\r →

← #AK\r

It is very important to notice that, even if the module is ON and regulating the output current correctly, an MWI command can generate a "Crowbar" intervention and a consequent fault if the current change step is too large, especially for large inductive loads; this is due to the large di(t)/dt that generates voltage peaks.

5.3.34 "PASSWORD" Command

The 'PASSWORD' command can be used to unlock the EEPROM cells that are password protected in order not to let inexperienced users to change some power supply parameters that might compromise the correct operation of the module.

See "EEPROM Memory Mapping" section for further details on password-protected cells.

The correct form format for this command is as follows:

PASSWORD:password\r

where:

- *password* is the module password to unlock protected EEPROM cells.

Replies from the power supply are in the form '#AK\r', or '#NAK\r'; this non-acknowledgment reply is generated, as it is for the MRM command, when:

- the written *password* is incorrect.

Examples:

PASSWORD example with a wrong password:

PASSWORD:elephant\r →

← #NAK\r

PASSWORD example with the right password:

PASSWORD:PS-ADMIN\r →

← #AK\r

The password to unlock password-protected cells is:

PS-ADMIN

5.4 IP Address Configuration

The easiest way to configure the DiRAC power supply unit IP address is to set it by the *Connectivity* menu on the unit LOCAL control – i.e. encoder and display (see section 4.2.5 for further details).

In other cases, when accessibility to the power supply by the user is not possible, there is the need to configure the IP address REMOTELY.

The situations can be mainly two:

- the actual power supply IP address is known by the user. In these case the new IP address configuration can be performed with one of the two following methods:
    - by using the SIP command (see section 5.3.23 for further details);
    - via a basic Telnet connection.
- the actual power supply IP address is NOT known by the user. In this case the new IP address configuration can be performed by using the DeviceInstaller® software.

An overview of the procedures to be followed using the just cited methods is herein presented.

5.4.1 IP Address configuration - SIP command

If the power supply IP address is know by the user, it is possible to configure the new IP address by using the SIP command.
This operation must be performed when:

- the power supply is in REMOTE mode;
- the power supply is OFF (it is necessary to disable the output with the MOFF command first for safety purposes);
- the sent IP address is correct.

If at least one of the three just cited conditions is not satisfied, the power supply will not operate any change in its IP address and will reply with a non-acknowledgment command.

The format used to set the IP address must be as follows:

SIP:ip_addr\r

If the DiRAC power supply actual IP address is known and there's an active connection to it, the configuration can be performed, for example, as follows.

SIP:192.168.0.55\r →

← #AK\r

Obviously, after the new IP is set, the Ethernet module will reset and the connection to the host PC (or device) will be lost. A new connection must be established to the new IP address - e.g. 192.168.0.55.

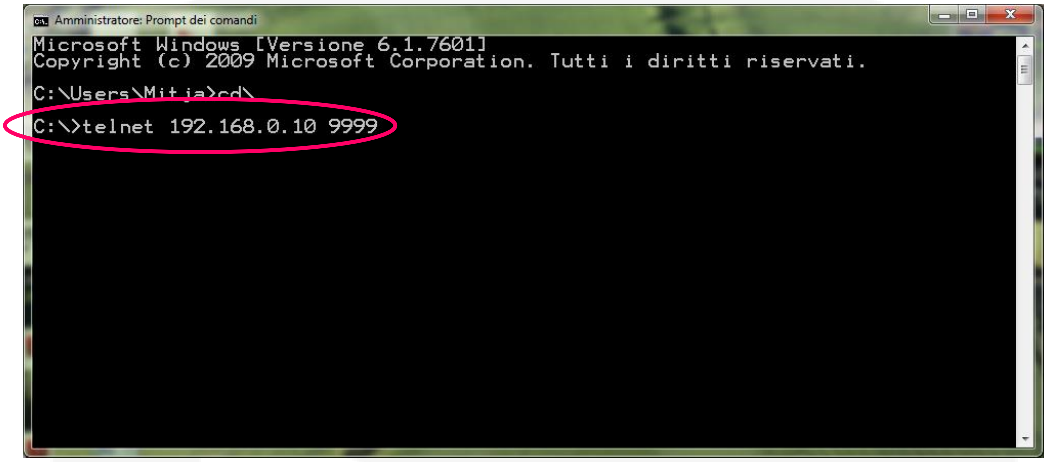
5.4.2 IP Address configuration - TELNET connection

If the power supply IP address is know by the user, it is also possible to configure the new IP address by using a simple TELNET connection.

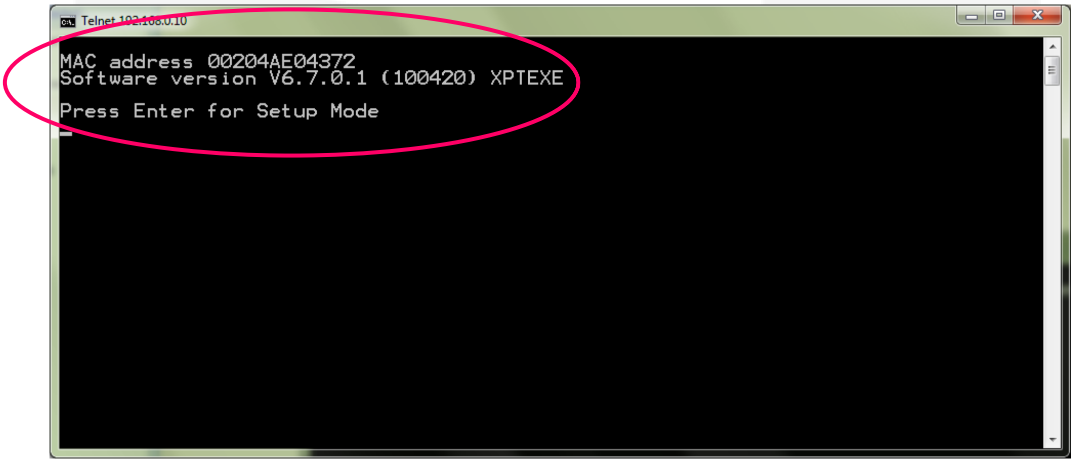
The TELNET connection must be established to **port 9999** of the Ethernet device of the power supply module.

Please carefully follow the instructions in order to correctly set/change the IP address of the A3660BS module:

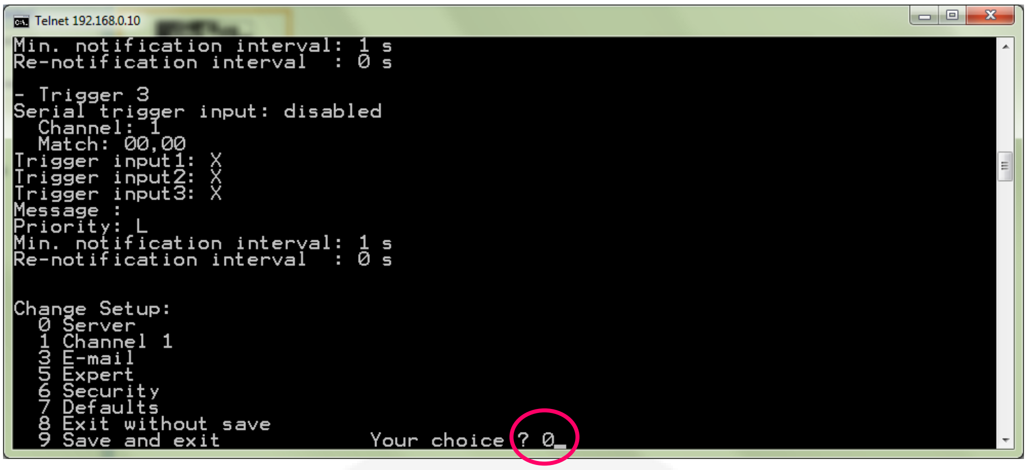
- establish a TELNET connection to port 9999 of the module IP address - e.g. 192.168.0.10;



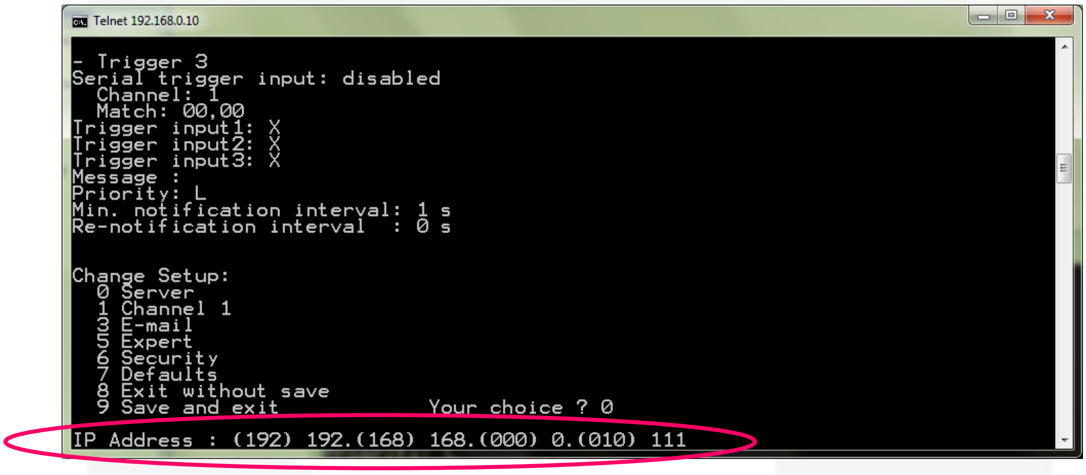
- now press Enter on the prompt to enter configuration menu;



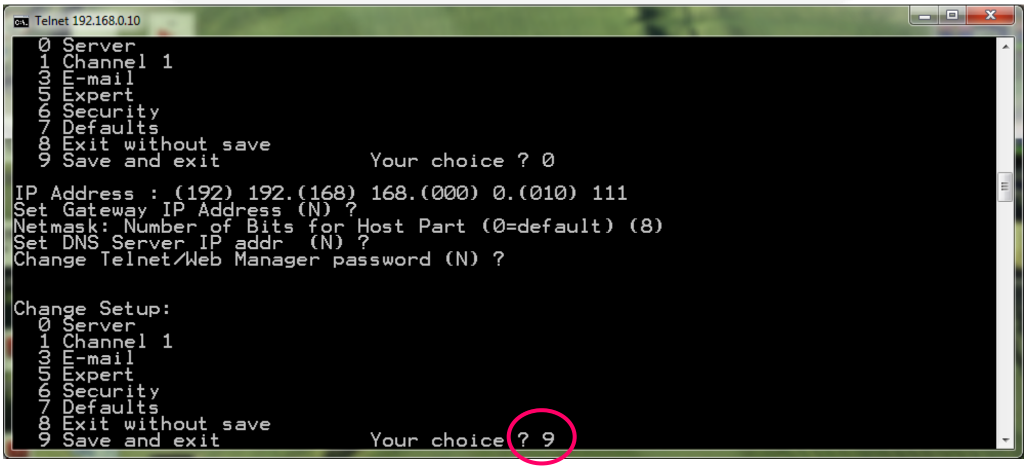
- on the device Telnet-based menu first select the "Server" option by inserting "0" and by pressing Enter on the prompt.



- when asked for the "IP Address" please enter the desired new IP address for the power supply. Please note that the IP address must be entered as 4 three-digit number - e.g. 192.168.0.111;



- Press the Enter key until reaching the "Your choice" screen again. Now insert "9" - i.e. Save and exit - and press Enter again.



The device should now reboot in order for the changes to take effect.

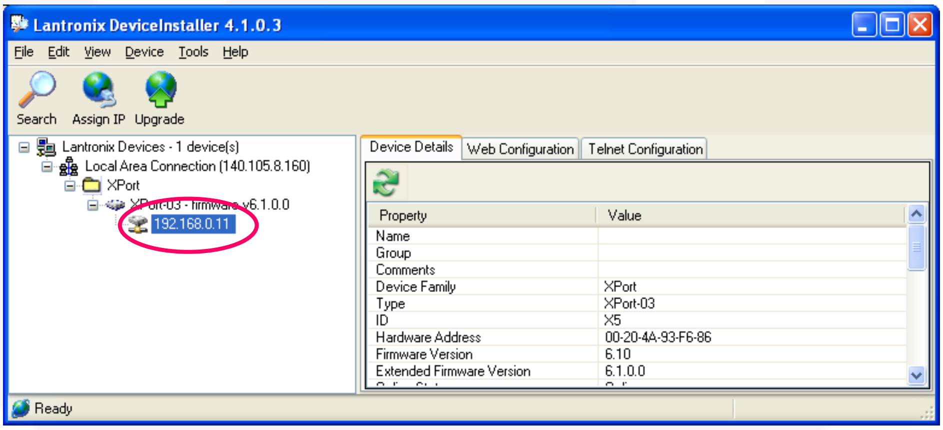
5.4.3 IP Address configuration - DeviceInstaller®

If the power supply IP address is not know by the user and local access to the module is not possible, the best way to find out and to configure the module IP address is to use the DeviceInstaller® software.

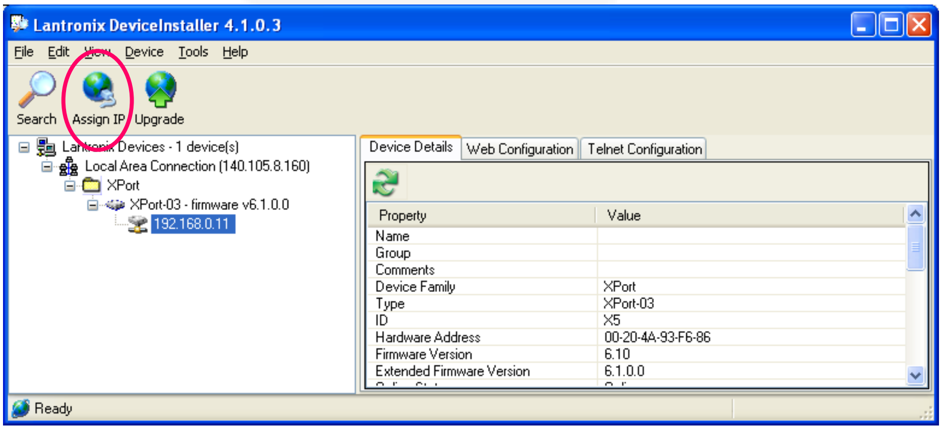
The DeviceInstaller® software can be downloaded for free from the Lantronix website www.lantronix.com.The DiRAC power supplies can be connected to a global LAN or point-to-point (recommended in order to obtain minimum delays, maximum speed performance and to avoid possible communication problems). Please note that for a point-to-point direct connection a twisted Ethernet cable must be used.

The next few steps must be followed in order to assign a new IP address to the module:

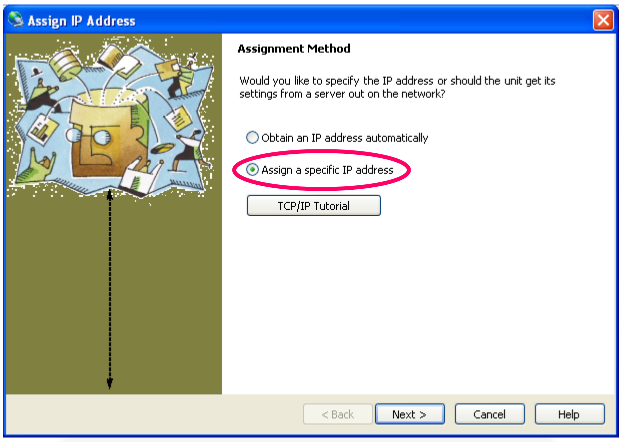
- Connect to the desired DiRAC module with a twisted Ethernet cable;
- Verify that the "Link LED" on the RJ45 connector is turned on (amber for a 10Mbps connection or green for a 100Mbps connection);
- Launch the "DeviceInstaller" program;
- Select the XPort device where you want to change the IP address;



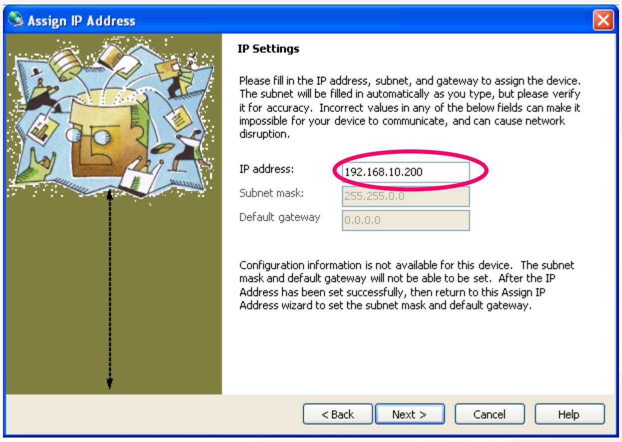
- Click on the "Assign IP" icon;



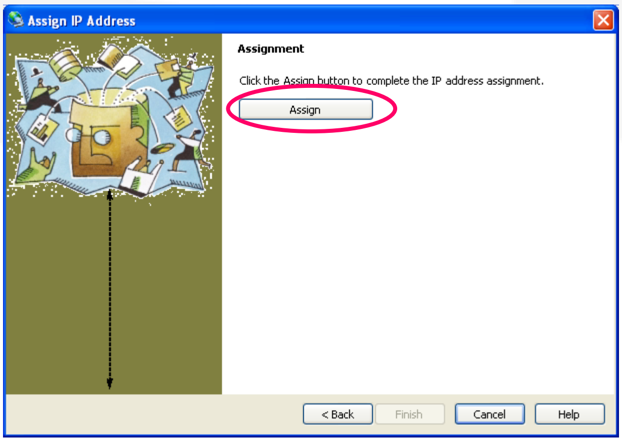
- Select "Assign a specific IP address" and then click "Next";



- Complete the "IP address" field and click on "Next";



- Click on the "Assign" button;



- Wait for the assignment procedure to end, and then click "Finish".

The new DiRAC power supply unit IP address should now be assigned and the success of the operation can be verified on the "DeviceInstaller" main window (if the window does not refresh, click on "Search").

6. Technical Specifications

Technical Specifications for the DiRAC monopolar power supply units are here presented.

	DiRAC Power Unit	
Rated output current	**PS120050** **PS135040**	120A 135A
Rated output voltage	**PS120050** **PS135040**	50 V 40 V
Input Voltage	A- version E- version	3 × 208 V(AC) @ 47-63 Hz 3 × 400 V(AC) @ 47-63 Hz
PF (Power Factor)	P_{OUT} > 1 kW P_{OUT} > 2 kW	> 0.98 > 0.99
Topology	Three-level ZVS converter	
Maximum output power	up to 6 kW	
Current setting resolution	18 bit	
Output current readback	20 bit	
Output voltage readback	20 bit	
Output current ripple*	100 ppm / FS	
Output current stability	20 ppm / FS	
AC/DC efficiency	up to 90%	
Switching Frequency	100 kHz	
Accuracy	< 0.01%	
Regulation Range	From A% to 100%*	
External Interlocks/States	4 Inputs: user-configurable contacts 2 Outputs: relay-type (1 magnetic + 1 solid-state)	

Internal Interlocks	Over-Temperature Earth Fault Current Regulation Fault Fan Fault AC Fault
Hardware protections	Load energy dumping (free-wheeling) Circuit breaker
Auxiliary ADC Read-Backs	Internal Temperatures Earth Leakage Current
Cooling	Air Convection - self-regulated fans
Connection	Ethernet TCP-IP / UDP
Extra-Features	Soft-Start mode Point-by-Point Current Waveform Loading User-definable interlock thresholds, active levels and timings FPGA Firmware Remote Updates User-settable Slew-Rate value
Dimensions	19" - 3U high Euro-mechanics rack

* minimum regulation current (A%) depending on the model and output ratings

Annex A - Output Connectors

Connections to the load from the DiRAC must be carried out using M8 or M10 screws on the output terminals. The corresponding signals are presented in **Figure 15**:

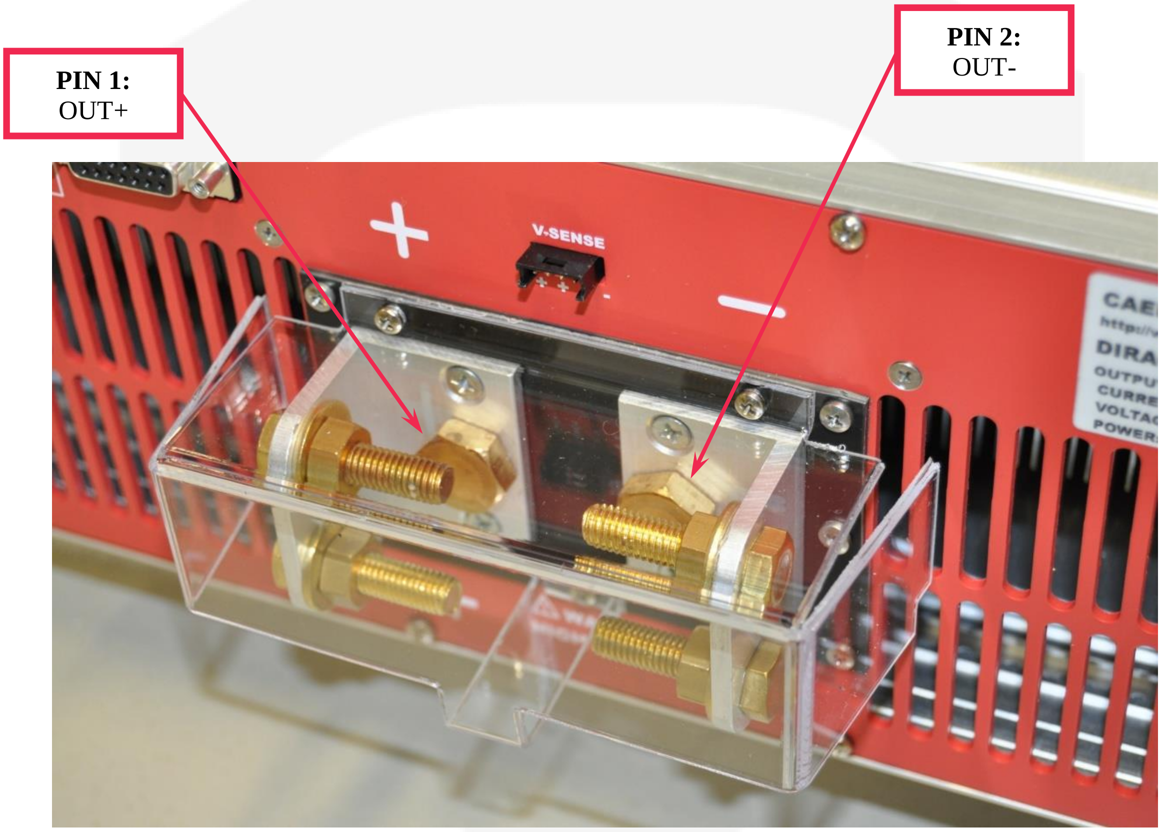


Figure 15: output connection terminals

The corresponding pinout is:

- **pin 1**: positive output terminal;
- **pin 2**: negative output terminal;

A rigid plastic insulation transparent cover is used in order to guarantee major safety on the high power contacts of the DiRAC power supply unit after installation.